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Phillips et al.

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(54) **BITRATE CONTROL IN A VIRTUAL REALITY (VR) ENVIRONMENT**

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(73) Assignee: **Telefonaktiebolaget LM Ericsson (Publ)**, Stockholm (SE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 47 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

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(51) **Int. Cl.**
H04N 21/2385 (2011.01)
H04N 21/436 (2011.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04N 21/2385*** (2013.01); ***H04N 21/2143*** (2013.01); ***H04N 21/41407*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04N 21/2143; H04N 21/2385; H04N 21/41407
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,975,283 B2 * 7/2011 Bedingfield, Sr. H04N 7/17318 725/12
8,767,014 B2 * 7/2014 Vaught G02B 27/017 345/633
(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 2016/129549 A1 8/2016

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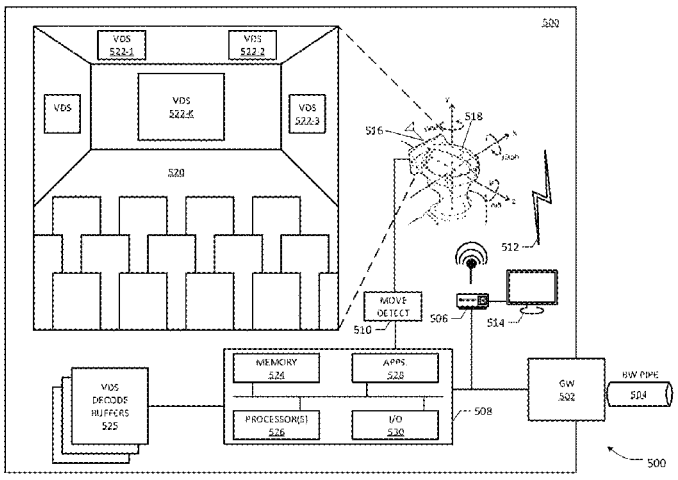
Assistant Examiner — Jaycee Imperial
(74) *Attorney, Agent, or Firm* — Christopher & Weisberg, P.A.

(57) **ABSTRACT**

A system and method for providing bitrate control for delivering media content to a plurality of virtual display (VD) screens presented in a virtual reality (VR) environment effectuated by a VR device of a subscriber based on detecting a movement in a point of view with respect the VD screens' placement within the VR environment, wherein each VD screen is configured to receive a media content channel. Responsive to detecting the movement, angular distance of each of the VD screens relative to a reference axis is computed. Weights to each of the media content channels may be assigned or updated based on the angular distance of the corresponding VD screens relative to the reference axis. Bandwidth of a managed bandwidth pipe may be (re)allocated based on the relative weights of the media content channels for delivering the media content channels to the subscriber's VR environment responsive to selecting single bitrates for the media channels according to a channel bandwidth annealing mechanism.

19 Claims, 54 Drawing Sheets



(51) **Int. Cl.**

H04N 21/61	(2011.01)
H04N 21/482	(2011.01)
H04N 21/4728	(2011.01)
H04N 21/214	(2011.01)
H04N 21/414	(2011.01)
H04N 21/4402	(2011.01)
H04N 21/442	(2011.01)
H04N 21/472	(2011.01)
H04N 21/6405	(2011.01)
H04N 21/643	(2011.01)
H04N 21/81	(2011.01)
H04N 21/845	(2011.01)

(52) **U.S. Cl.**

CPC . ***H04N 21/43615*** (2013.01); ***H04N 21/44218*** (2013.01); ***H04N 21/440245*** (2013.01); ***H04N 21/4728*** (2013.01); ***H04N 21/47217*** (2013.01); ***H04N 21/482*** (2013.01); ***H04N 21/6118*** (2013.01); ***H04N 21/6125*** (2013.01); ***H04N 21/6405*** (2013.01); ***H04N 21/64322*** (2013.01); ***H04N 21/816*** (2013.01); ***H04N 21/8456*** (2013.01)

(58) **Field of Classification Search**

USPC 725/10

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,392,212	B1	7/2016	Ross	
9,918,136	B2 *	3/2018	Cole	H04N 13/161
10,140,000	B2 *	11/2018	Grossman	G06F 3/04815
2007/0292038	A1 *	12/2007	Takemoto	G06T 5/009 382/240
2014/0168277	A1 *	6/2014	Ashley	G06F 3/1446 345/672
2014/0195675	A1 *	7/2014	Silver	H04L 65/607 709/224
2015/0212576	A1	7/2015	Ambrus et al.	
2015/0288732	A1	10/2015	Phillips et al.	
2015/0346812	A1	12/2015	Cole et al.	
2016/0044080	A1 *	2/2016	DuBreuil	H04L 65/602 709/219
2017/0347135	A1 *	11/2017	Frantz	H04N 21/8456
2018/0063576	A1 *	3/2018	Tillman	H04N 21/44
2019/0191203	A1 *	6/2019	Asbun	H04N 21/2668

* cited by examiner

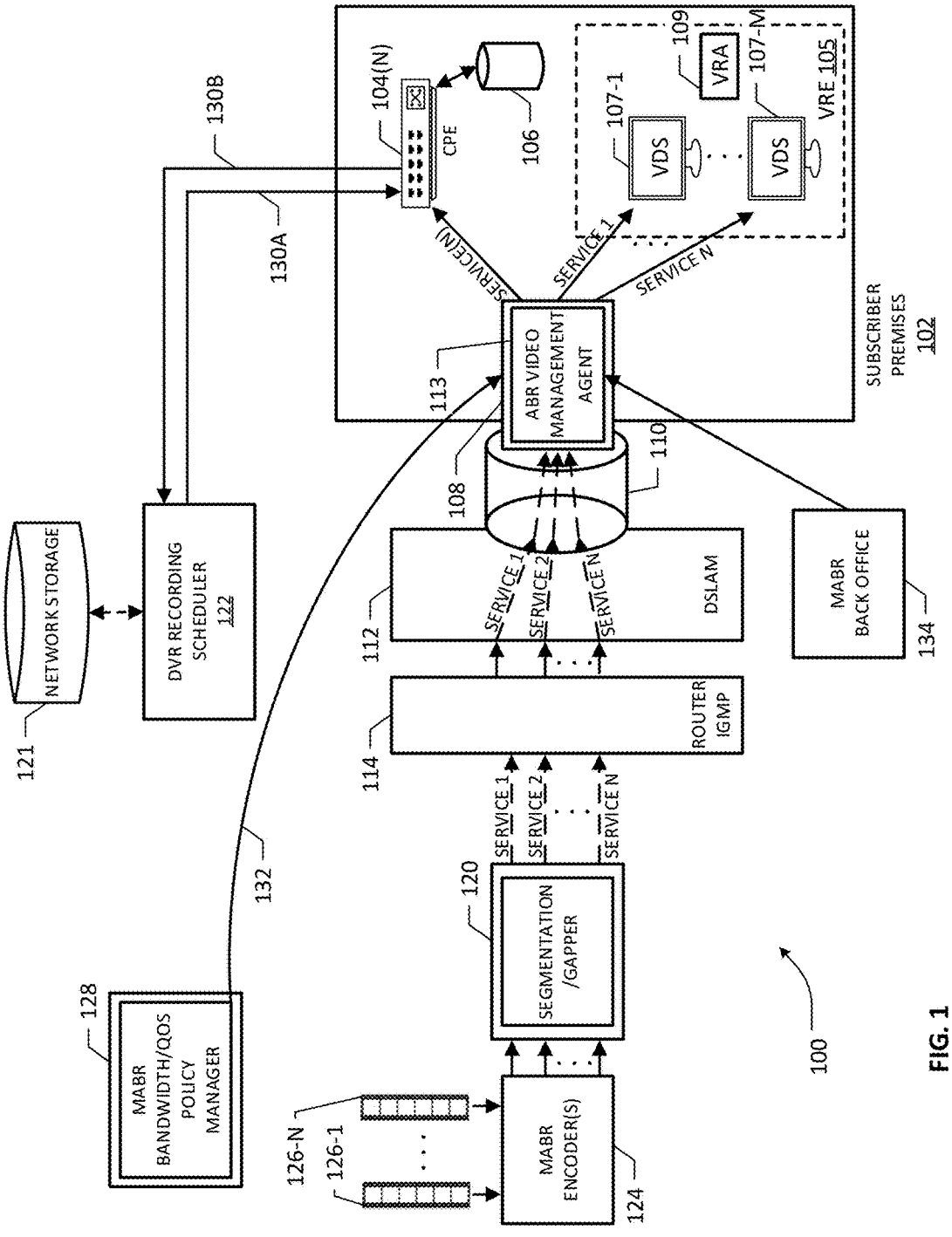

SUBSCRIBER PREMISES 102
104(N)
CPE
106
107-1
VDS
VDS
107-M
109
VRA
VRE 105
SERVICE(N)
SERVICE 1
SERVICE N
130B
130A
113
ABR VIDEO MANAGEMENT AGENT
108
110
112
DSLAM
SERVICE 1
SERVICE 2
SERVICE N
MABR BACK OFFICE
134
NETWORK STORAGE
121
DVR RECORDING SCHEDULER 122
114
ROUTER IGMP
SERVICE 1
SERVICE 2
SERVICE N
120
SEGMENTATION /GAPPER
132
128
MABR BANDWIDTH/QOS POLICY MANAGER
126-N
126-1
MABR ENCODER(S)
124
100

FIG. 1

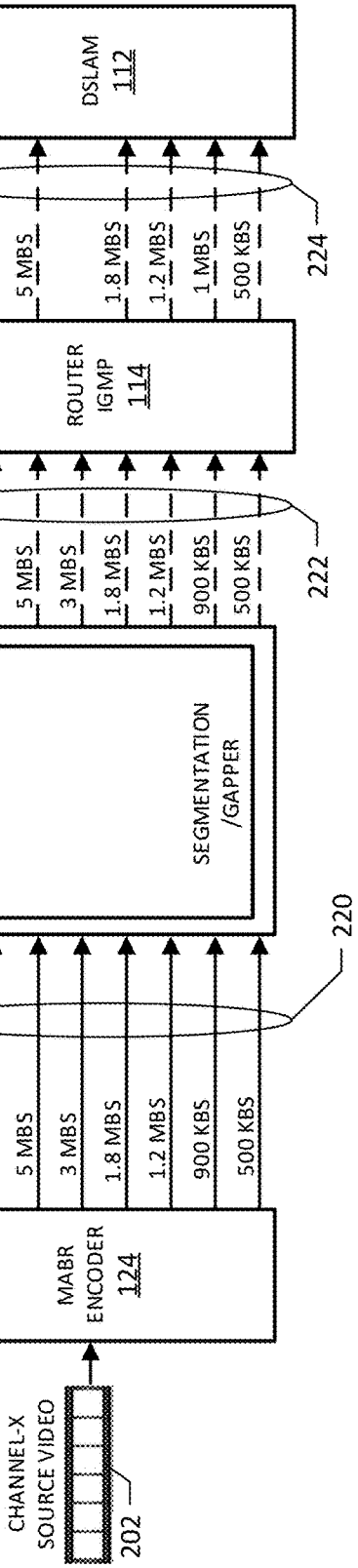

DSLAM
112
10 MBS
5 MBS
1.8 MBS
1.2 MBS
1 MBS
500 KBS
224
ROUTER
IGMP
114
10 MBS
7 MBS
5 MBS
3 MBS
1.8 MBS
1.2 MBS
900 KBS
500 KBS
222
120
SEGMENTATION
/GAPPER
220
10 MBS
7 MBS
5 MBS
3 MBS
1.8 MBS
1.2 MBS
900 KBS
500 KBS
MABR
ENCODER
124
CHANNEL-X
SOURCE VIDEO
202
200

FIG. 2

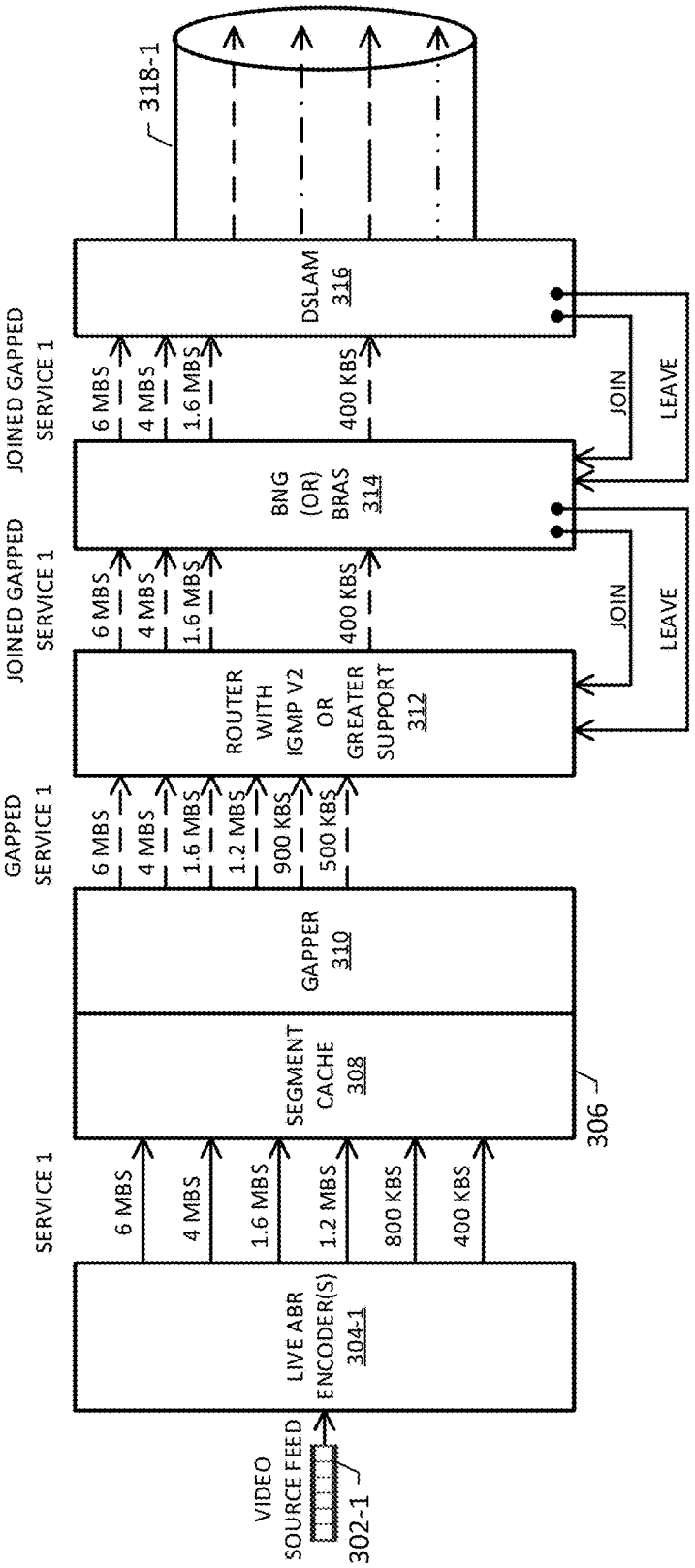

VIDEO SOURCE FEED
302-1
LIVE ABR ENCODER(S) 304-1
SERVICE 1
6 MBS
4 MBS
1.6 MBS
1.2 MBS
800 KBS
400 KBS
SEGMENT CACHE 308
GAPPER 310
306
GAPPED SERVICE 1
6 MBS
4 MBS
1.6 MBS
1.2 MBS
900 KBS
500 KBS
ROUTER WITH IGMP V2 OR GREATER SUPPORT 312
JOINED GAPPED SERVICE 1
6 MBS
4 MBS
1.6 MBS
400 KBS
JOIN
LEAVE
BNG (OR) BRAS 314
JOINED GAPPED SERVICE 1
6 MBS
4 MBS
1.6 MBS
400 KBS
JOIN
LEAVE
DSLAM 316
318-1
300A

FIG 3A

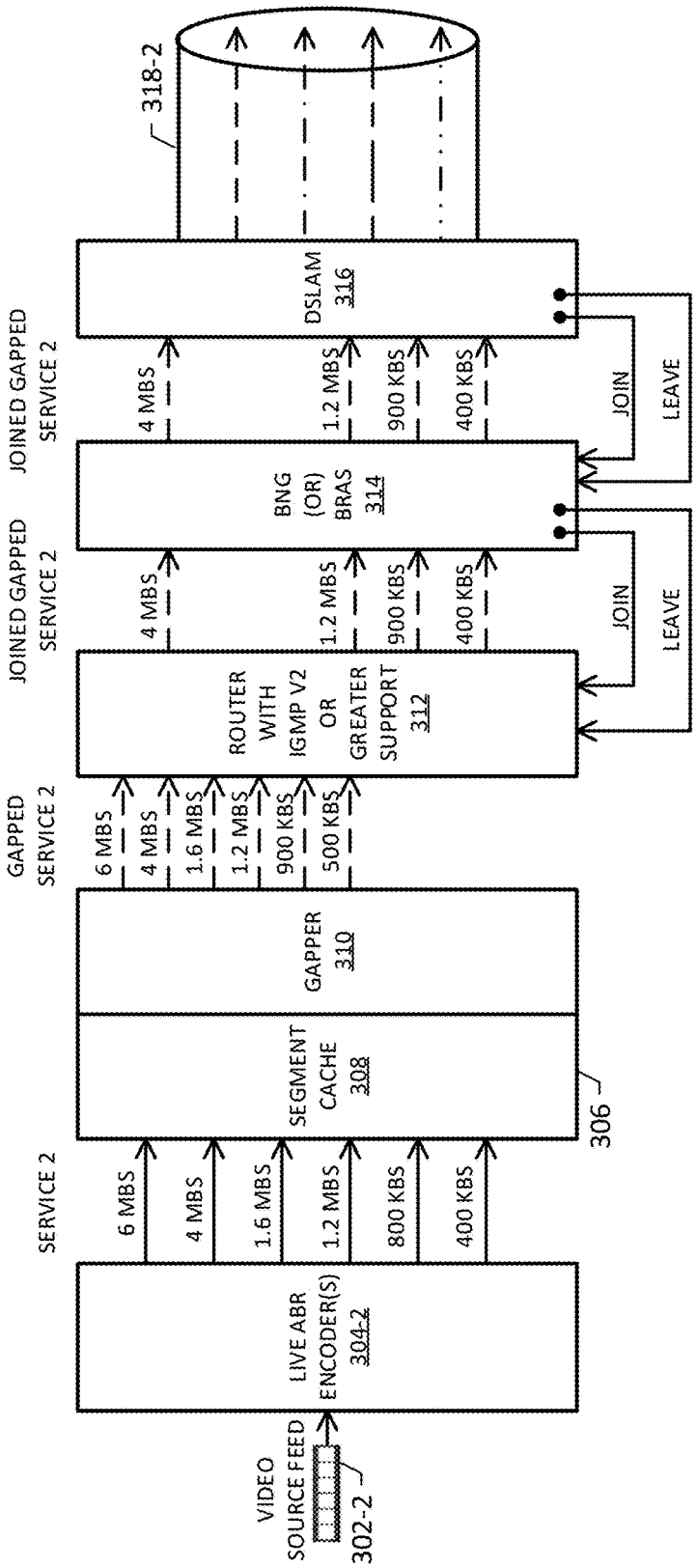

VIDEO SOURCE FEED
302-2
LIVE ABR ENCODER(S) 304-2
SERVICE 2
6 MBS
4 MBS
1.6 MBS
1.2 MBS
800 KBS
400 KBS
SEGMENT CACHE 308
GAPPER 310
306
GAPPED SERVICE 2
6 MBS
4 MBS
1.6 MBS
1.2 MBS
900 KBS
500 KBS
ROUTER WITH IGMP V2 OR GREATER SUPPORT 312
JOINED GAPPED SERVICE 2
4 MBS
1.2 MBS
900 KBS
400 KBS
JOIN
LEAVE
BNG (OR) BRAS 314
JOINED GAPPED SERVICE 2
4 MBS
1.2 MBS
900 KBS
400 KBS
JOIN
LEAVE
DSLAM 316
318-2
300B

FIG 3B

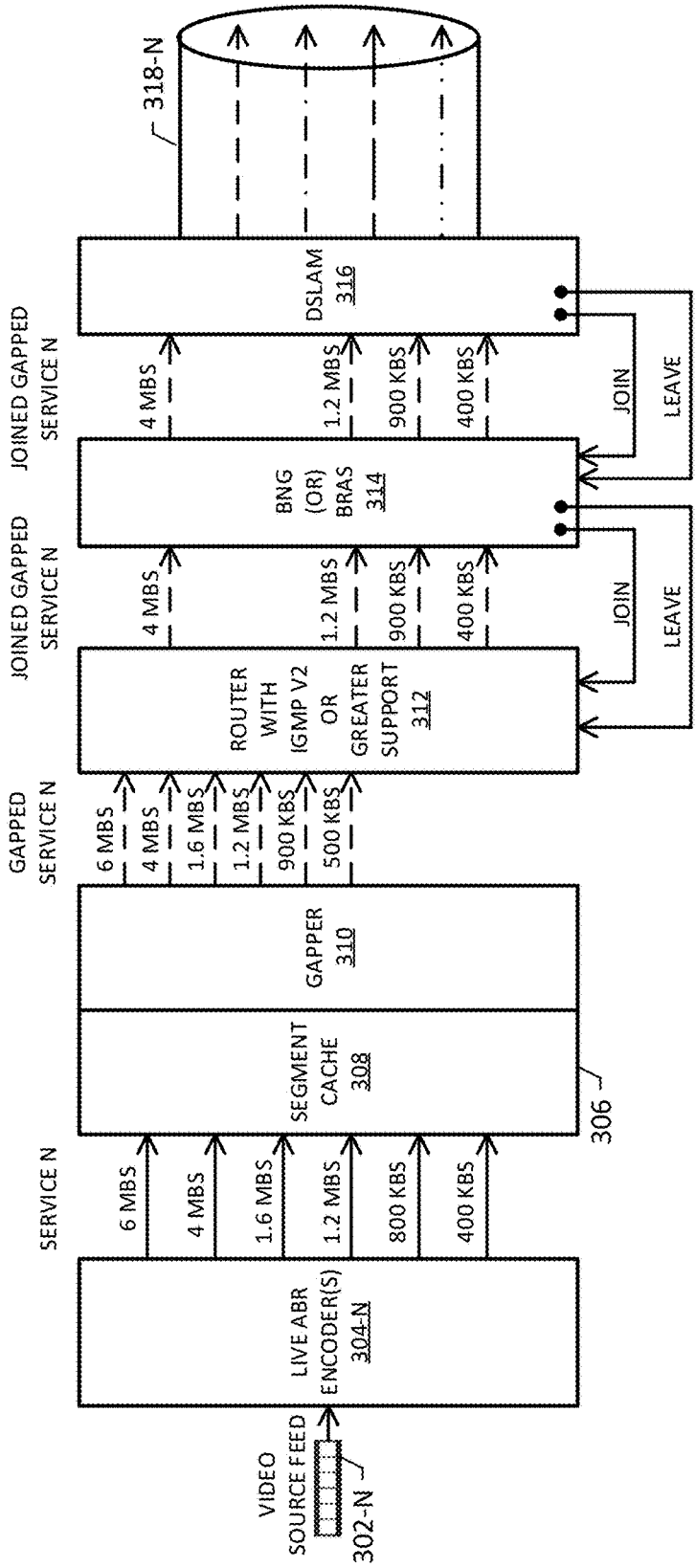

318-N
DSLAM 316
JOIN
LEAVE
4 MBS
1.2 MBS
900 KBS
400 KBS
JOINED GAPPED SERVICE N
BNG (OR) BRAS 314
ROUTER WITH IGMP V2 OR GREATER SUPPORT 312
GAPPED SERVICE N
6 MBS
1.6 MBS
500 KBS
GAPPER 310
SEGMENT CACHE 308
306
SERVICE N
800 KBS
LIVE ABR ENCODER(S) 304-N
VIDEO SOURCE FEED
302-N
300C

FIG 3C

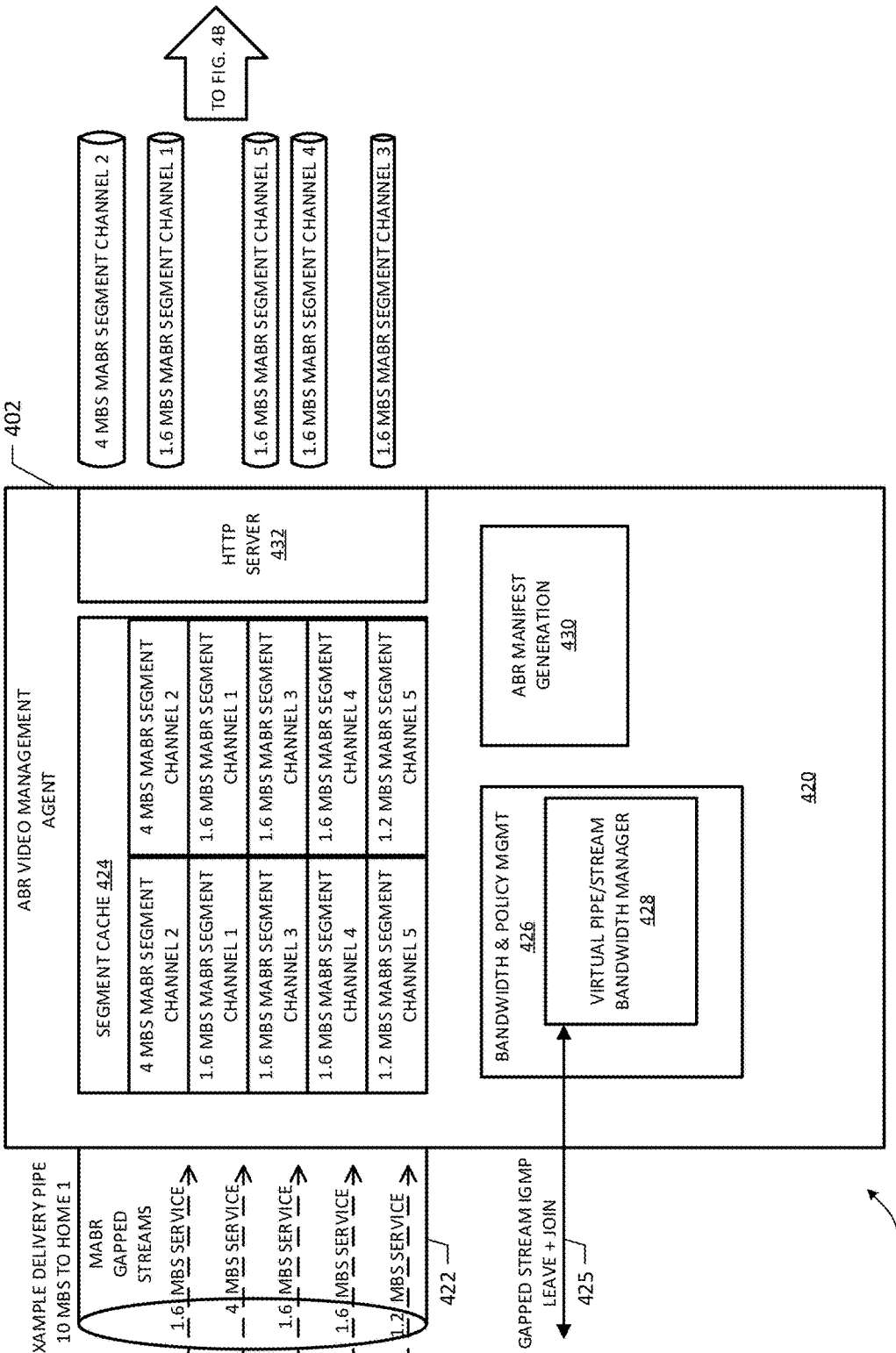

EXAMPLE DELIVERY PIPE
10 MBS TO HOME 1
MABR GAPPED STREAMS
1.6 MBS SERVICE
4 MBS SERVICE
1.6 MBS SERVICE
1.6 MBS SERVICE
1.2 MBS SERVICE
422
GAPPED STREAM IGMP LEAVE + JOIN
425
400A
ABR VIDEO MANAGEMENT AGENT
402
SEGMENT CACHE 424
4 MBS MABR SEGMENT CHANNEL 2
1.6 MBS MABR SEGMENT CHANNEL 1
1.6 MBS MABR SEGMENT CHANNEL 3
1.6 MBS MABR SEGMENT CHANNEL 4
1.2 MBS MABR SEGMENT CHANNEL 5
HTTP SERVER 432
ABR MANIFEST GENERATION 430
BANDWIDTH & POLICY MGMT 426
VIRTUAL PIPE/STREAM BANDWIDTH MANAGER 428
420
4 MBS MABR SEGMENT CHANNEL 2
1.6 MBS MABR SEGMENT CHANNEL 1
1.6 MBS MABR SEGMENT CHANNEL 5
1.6 MBS MABR SEGMENT CHANNEL 4
1.6 MBS MABR SEGMENT CHANNEL 3
TO FIG. 4B

FIG. 4A

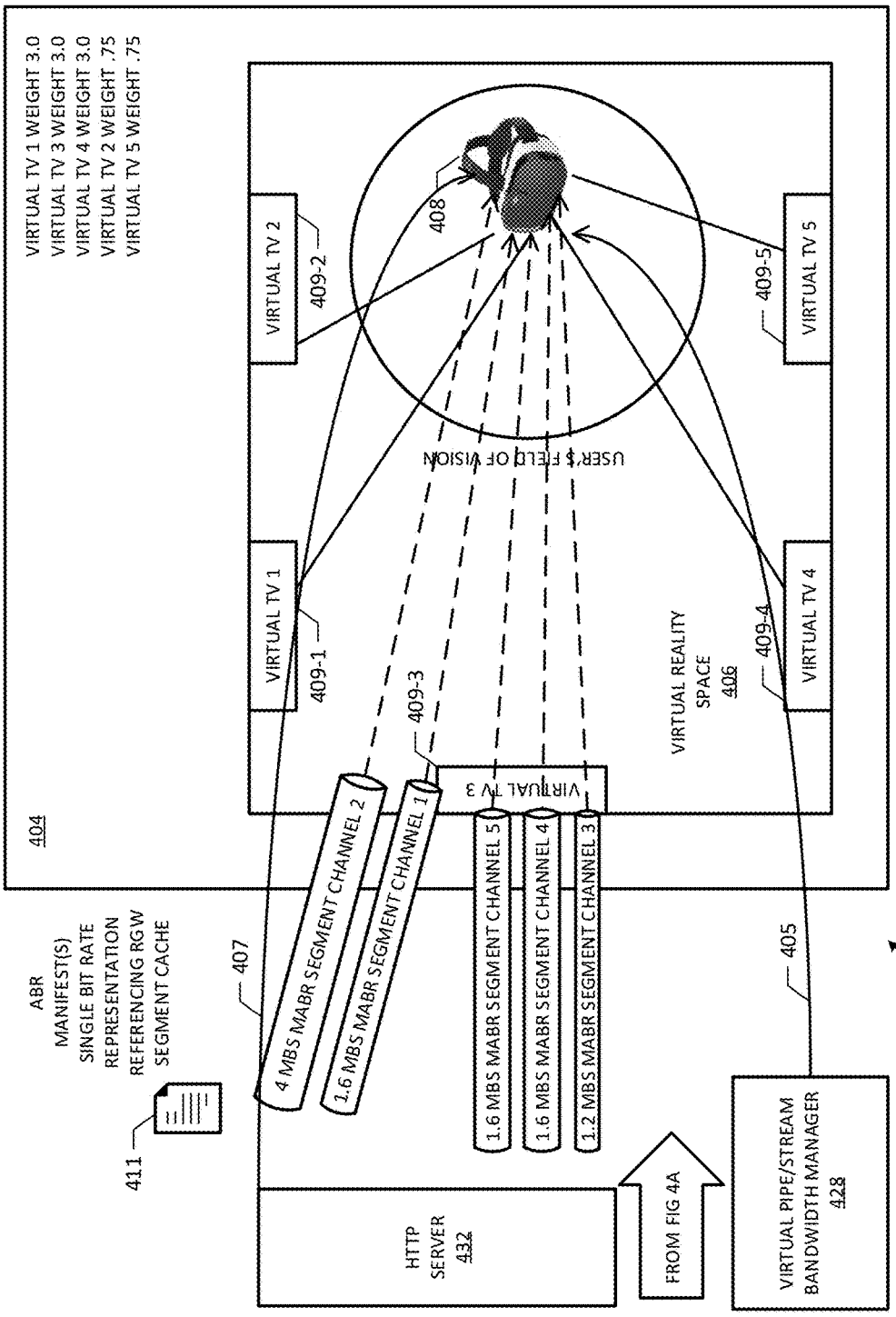

VIRTUAL TV 1 WEIGHT 3.0
VIRTUAL TV 3 WEIGHT 3.0
VIRTUAL TV 4 WEIGHT 3.0
VIRTUAL TV 2 WEIGHT .75
VIRTUAL TV 5 WEIGHT .75
404
VIRTUAL TV 1
409-1
VIRTUAL TV 2
409-2
VIRTUAL TV 3
409-3
VIRTUAL TV 4
409-4
VIRTUAL TV 5
409-5
408
USER'S FIELD OF VISION
VIRTUAL REALITY SPACE 406
4 MBS MABR SEGMENT CHANNEL 2
1.6 MBS MABR SEGMENT CHANNEL 1
1.6 MBS MABR SEGMENT CHANNEL 5
1.6 MBS MABR SEGMENT CHANNEL 4
1.2 MBS MABR SEGMENT CHANNEL 3
407
405
400B
ABR MANIFEST(S) SINGLE BIT RATE REPRESENTATION REFERENCING RGW SEGMENT CACHE
411
HTTP SERVER 432
FROM FIG 4A
VIRTUAL PIPE/STREAM BANDWIDTH MANAGER 428

FIG. 4B

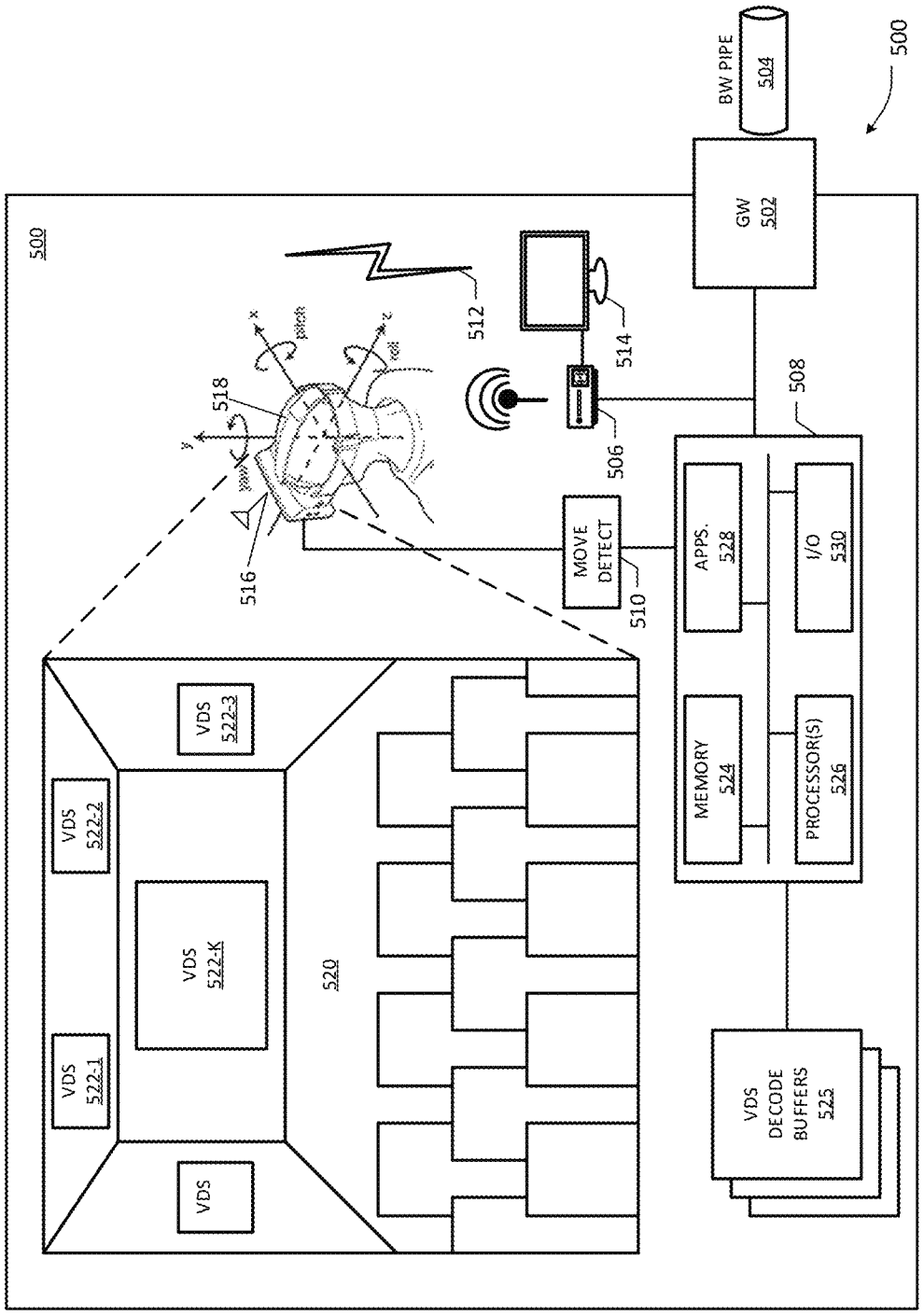

500
BW PIPE
504
GW
502
512
514
506
508
518
516
MOVE
DETECT
510
APPS.
528
I/O
530
MEMORY
524
PROCESSOR(S)
526
VDS
DECODE
BUFFERS
525
520
VDS
522-1
VDS
522-2
VDS
522-3
VDS
522-K
VDS

FIG. 5

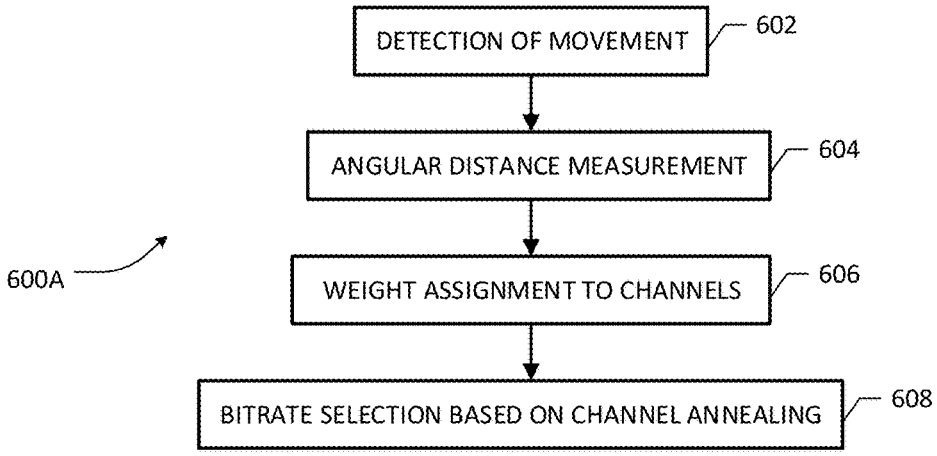

DETECTION OF MOVEMENT
602
ANGULAR DISTANCE MEASUREMENT
604
600A
WEIGHT ASSIGNMENT TO CHANNELS
606
BITRATE SELECTION BASED ON CHANNEL ANNEALING
608

FIG. 6A

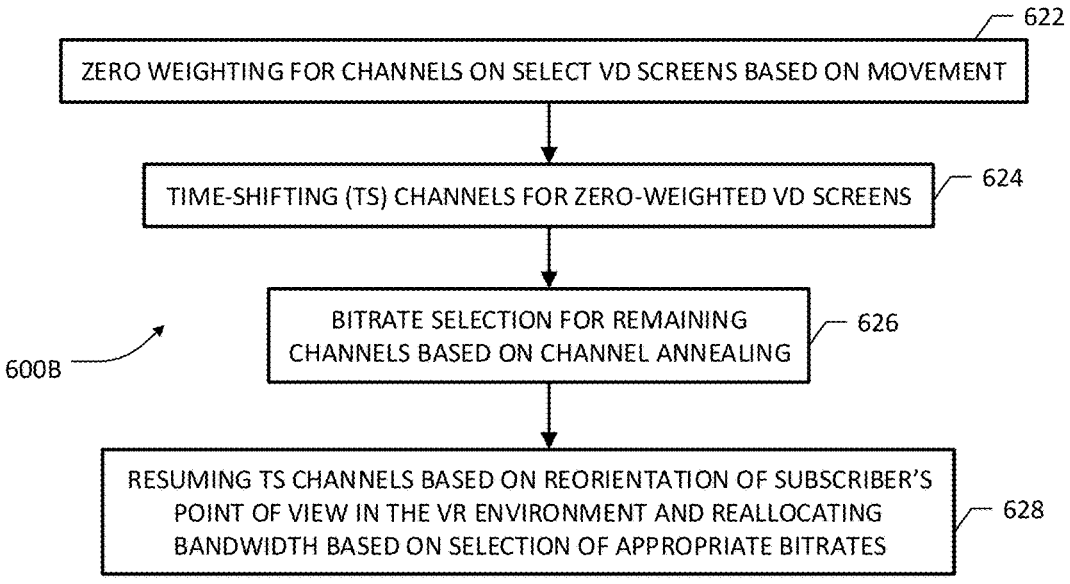

622
ZERO WEIGHTING FOR CHANNELS ON SELECT VD SCREENS BASED ON MOVEMENT
TIME-SHIFTING (TS) CHANNELS FOR ZERO-WEIGHTED VD SCREENS
624
600B
BITRATE SELECTION FOR REMAINING CHANNELS BASED ON CHANNEL ANNEALING
626
RESUMING TS CHANNELS BASED ON REORIENTATION OF SUBSCRIBER'S POINT OF VIEW IN THE VR ENVIRONMENT AND REALLOCATING BANDWIDTH BASED ON SELECTION OF APPROPRIATE BITRATES
628

FIG. 6B

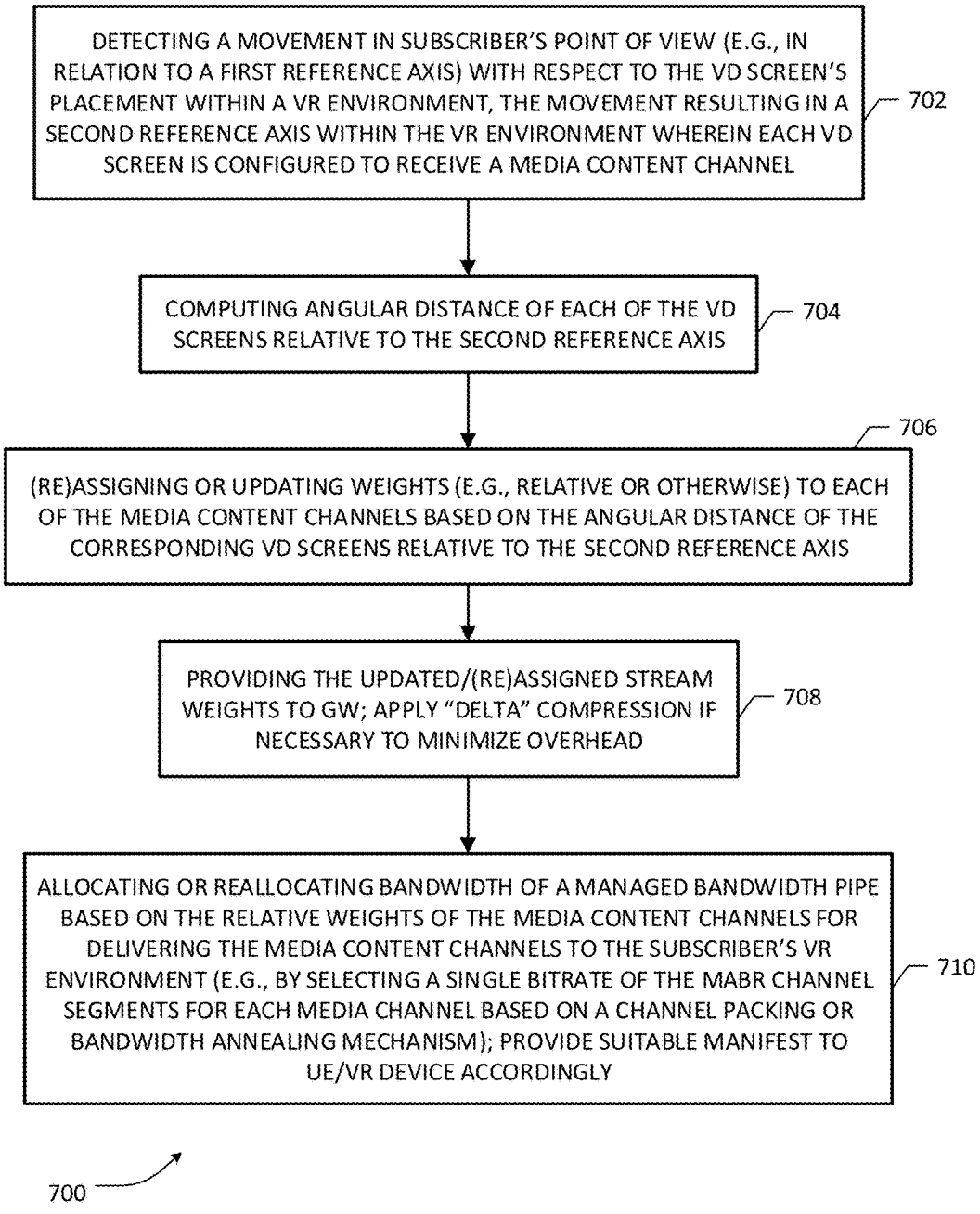

DETECTING A MOVEMENT IN SUBSCRIBER'S POINT OF VIEW (E.G., IN RELATION TO A FIRST REFERENCE AXIS) WITH RESPECT TO THE VD SCREEN'S PLACEMENT WITHIN A VR ENVIRONMENT, THE MOVEMENT RESULTING IN A SECOND REFERENCE AXIS WITHIN THE VR ENVIRONMENT WHEREIN EACH VD SCREEN IS CONFIGURED TO RECEIVE A MEDIA CONTENT CHANNEL
702
COMPUTING ANGULAR DISTANCE OF EACH OF THE VD SCREENS RELATIVE TO THE SECOND REFERENCE AXIS
704
706
(RE)ASSIGNING OR UPDATING WEIGHTS (E.G., RELATIVE OR OTHERWISE) TO EACH OF THE MEDIA CONTENT CHANNELS BASED ON THE ANGULAR DISTANCE OF THE CORRESPONDING VD SCREENS RELATIVE TO THE SECOND REFERENCE AXIS
PROVIDING THE UPDATED/(RE)ASSIGNED STREAM WEIGHTS TO GW; APPLY "DELTA" COMPRESSION IF NECESSARY TO MINIMIZE OVERHEAD
708
ALLOCATING OR REALLOCATING BANDWIDTH OF A MANAGED BANDWIDTH PIPE BASED ON THE RELATIVE WEIGHTS OF THE MEDIA CONTENT CHANNELS FOR DELIVERING THE MEDIA CONTENT CHANNELS TO THE SUBSCRIBER'S VR ENVIRONMENT (E.G., BY SELECTING A SINGLE BITRATE OF THE MABR CHANNEL SEGMENTS FOR EACH MEDIA CHANNEL BASED ON A CHANNEL PACKING OR BANDWIDTH ANNEALING MECHANISM); PROVIDE SUITABLE MANIFEST TO UE/VR DEVICE ACCORDINGLY
710
700

FIG. 7

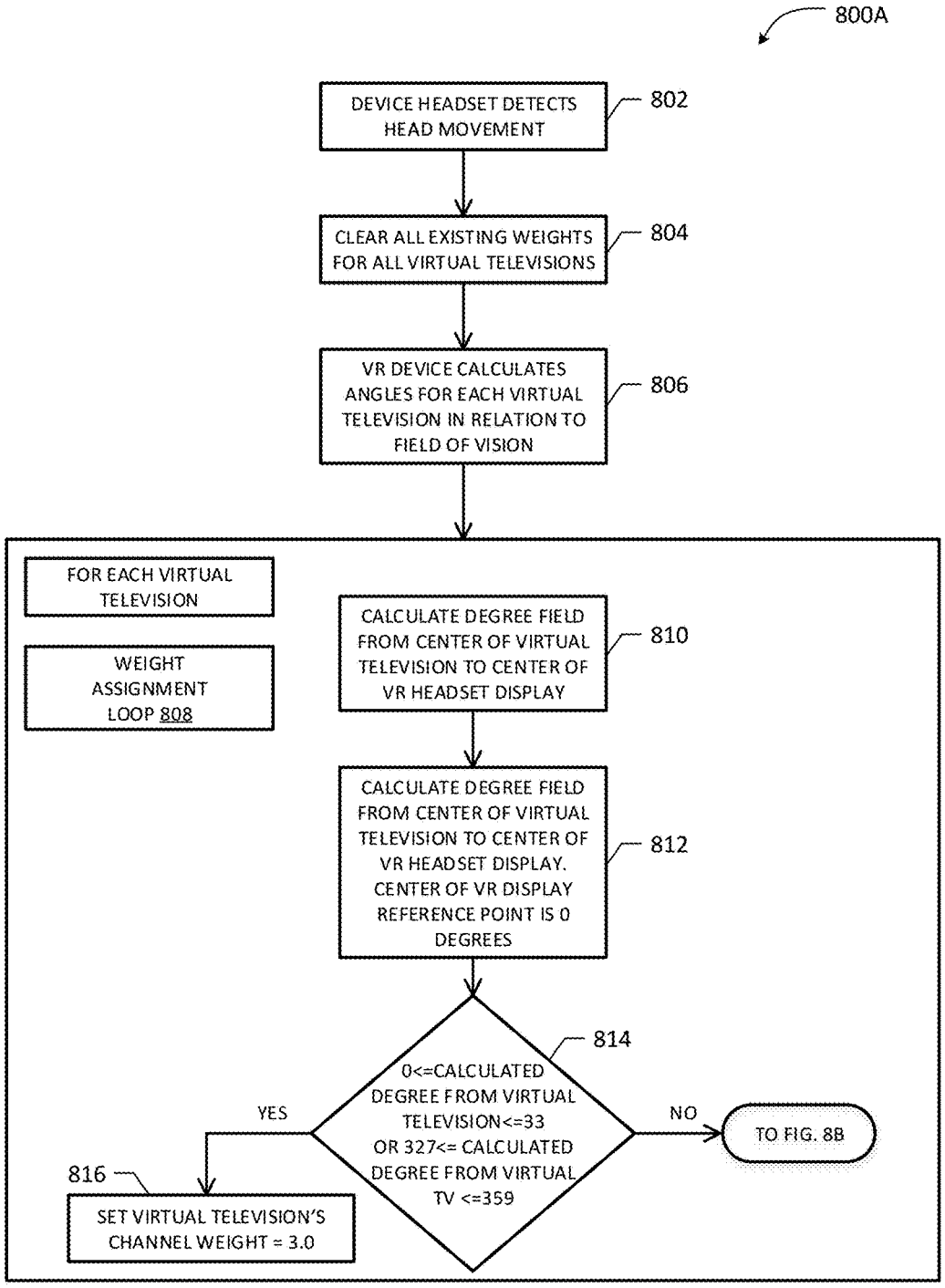

800A
DEVICE HEADSET DETECTS HEAD MOVEMENT
802
CLEAR ALL EXISTING WEIGHTS FOR ALL VIRTUAL TELEVISIONS
804
VR DEVICE CALCULATES ANGLES FOR EACH VIRTUAL TELEVISION IN RELATION TO FIELD OF VISION
806
FOR EACH VIRTUAL TELEVISION
WEIGHT ASSIGNMENT LOOP 808
CALCULATE DEGREE FIELD FROM CENTER OF VIRTUAL TELEVISION TO CENTER OF VR HEADSET DISPLAY
810
CALCULATE DEGREE FIELD FROM CENTER OF VIRTUAL TELEVISION TO CENTER OF VR HEADSET DISPLAY. CENTER OF VR DISPLAY REFERENCE POINT IS 0 DEGREES
812
0<=CALCULATED DEGREE FROM VIRTUAL TELEVISION<=33 OR 327<= CALCULATED DEGREE FROM VIRTUAL TV <=359
814
YES
NO
TO FIG. 8B
816
SET VIRTUAL TELEVISION'S CHANNEL WEIGHT = 3.0

FIG. 8A

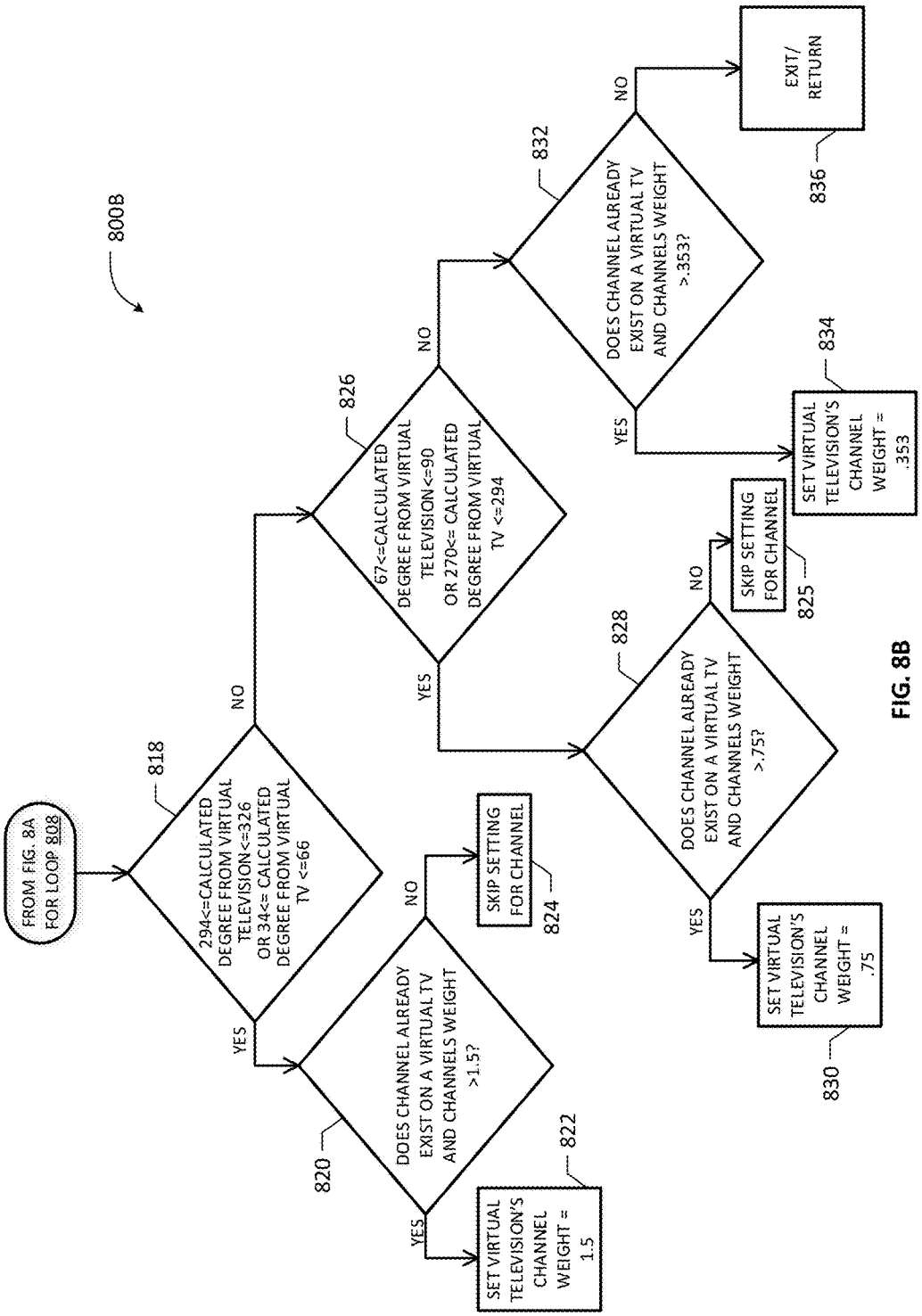

800B
FROM FIG. 8A FOR LOOP 808
818
294<=CALCULATED DEGREE FROM VIRTUAL TELEVISION<=326 OR 34<= CALCULATED DEGREE FROM VIRTUAL TV <=66
YES
NO
820
DOES CHANNEL ALREADY EXIST ON A VIRTUAL TV AND CHANNELS WEIGHT >1.5?
YES
NO
822
SET VIRTUAL TELEVISION'S CHANNEL WEIGHT = 1.5
824
SKIP SETTING FOR CHANNEL
826
67<=CALCULATED DEGREE FROM VIRTUAL TELEVISION<=90 OR 270<= CALCULATED DEGREE FROM VIRTUAL TV <=294
YES
NO
828
DOES CHANNEL ALREADY EXIST ON A VIRTUAL TV AND CHANNELS WEIGHT >.75?
YES
NO
830
SET VIRTUAL TELEVISION'S CHANNEL WEIGHT = .75
825
SKIP SETTING FOR CHANNEL
832
DOES CHANNEL ALREADY EXIST ON A VIRTUAL TV AND CHANNELS WEIGHT >.353?
YES
NO
834
SET VIRTUAL TELEVISION'S CHANNEL WEIGHT = .353
836
EXIT/ RETURN

FIG. 8B

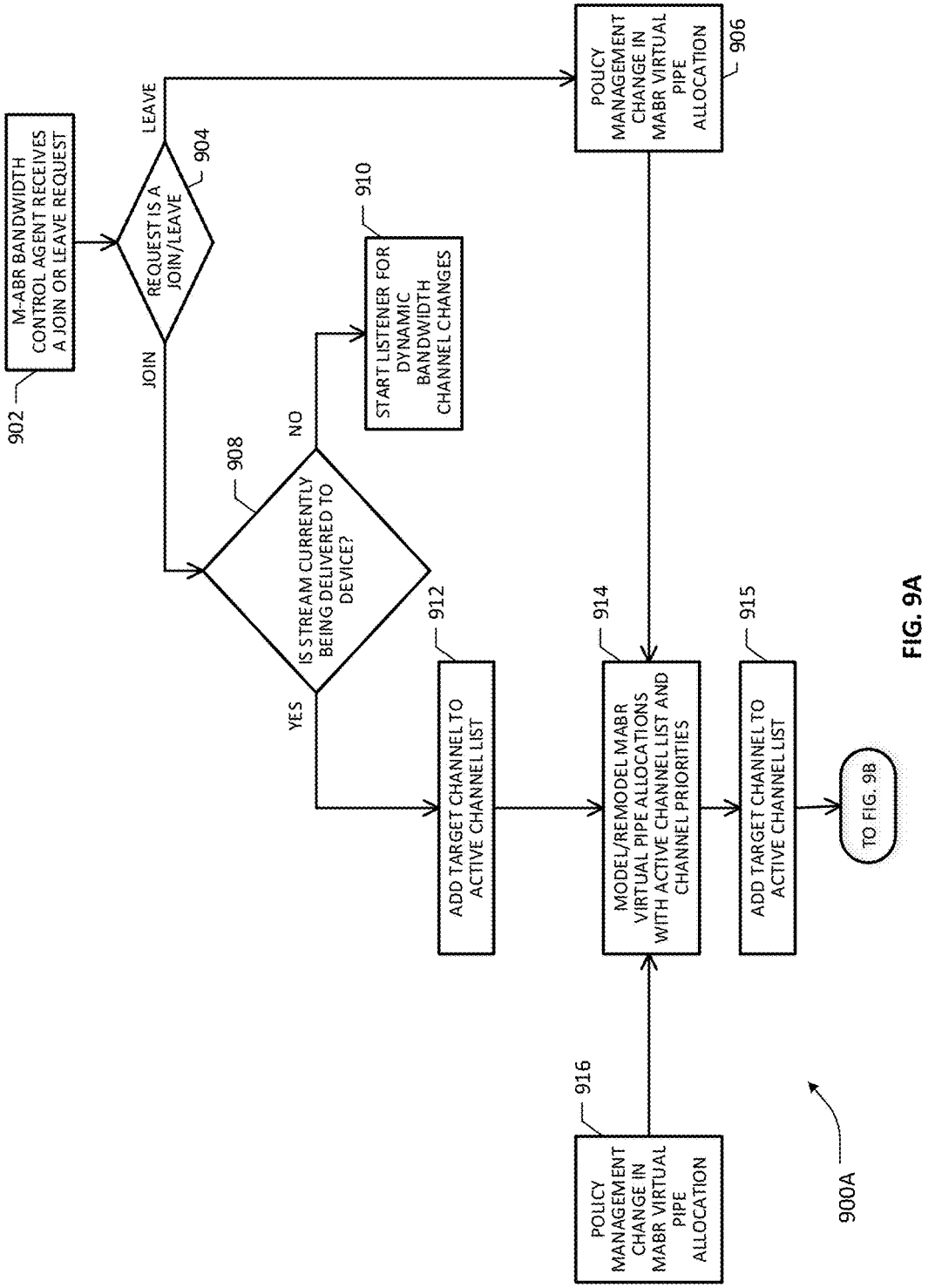

M-ABR BANDWIDTH CONTROL AGENT RECEIVES A JOIN OR LEAVE REQUEST
902
REQUEST IS A JOIN/LEAVE
904
LEAVE
JOIN
POLICY MANAGEMENT CHANGE IN MABR VIRTUAL PIPE ALLOCATION
906
START LISTENER FOR DYNAMIC BANDWIDTH CHANNEL CHANGES
910
NO
IS STREAM CURRENTLY BEING DELIVERED TO DEVICE?
908
YES
ADD TARGET CHANNEL TO ACTIVE CHANNEL LIST
912
MODEL/REMODEL MABR VIRTUAL PIPE ALLOCATIONS WITH ACTIVE CHANNEL LIST AND CHANNEL PRIORITIES
914
ADD TARGET CHANNEL TO ACTIVE CHANNEL LIST
915
TO FIG. 9B
POLICY MANAGEMENT CHANGE IN MABR VIRTUAL PIPE ALLOCATION
916
900A

FIG. 9A

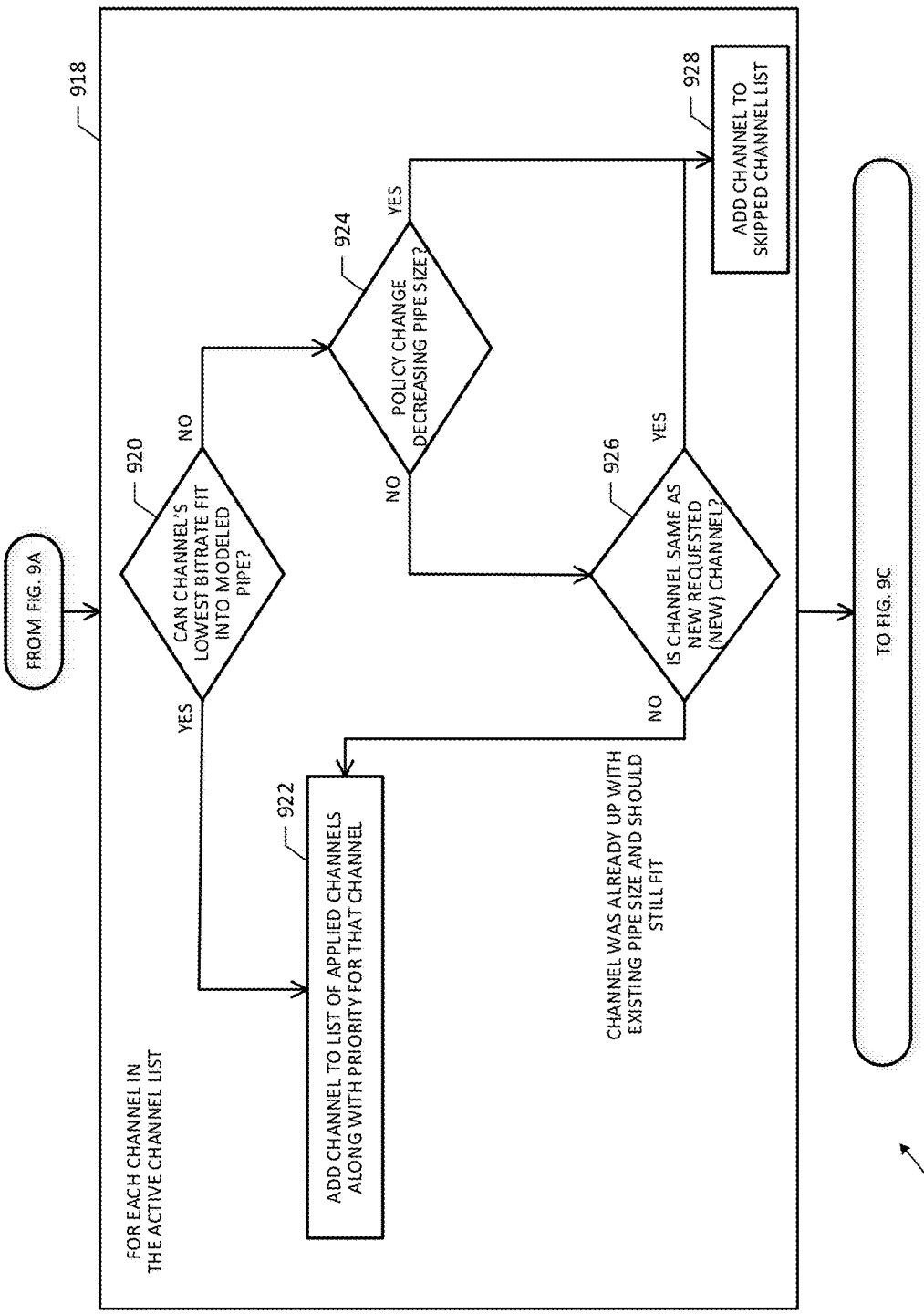

FROM FIG. 9A
918
FOR EACH CHANNEL IN THE ACTIVE CHANNEL LIST
920
CAN CHANNEL'S LOWEST BITRATE FIT INTO MODELED PIPE?
YES
NO
922
ADD CHANNEL TO LIST OF APPLIED CHANNELS ALONG WITH PRIORITY FOR THAT CHANNEL
924
POLICY CHANGE DECREASING PIPE SIZE?
YES
NO
926
IS CHANNEL SAME AS NEW REQUESTED (NEW) CHANNEL?
YES
NO
CHANNEL WAS ALREADY UP WITH EXISTING PIPE SIZE AND SHOULD STILL FIT
928
ADD CHANNEL TO SKIPPED CHANNEL LIST
TO FIG. 9C
900B

FIG. 9B

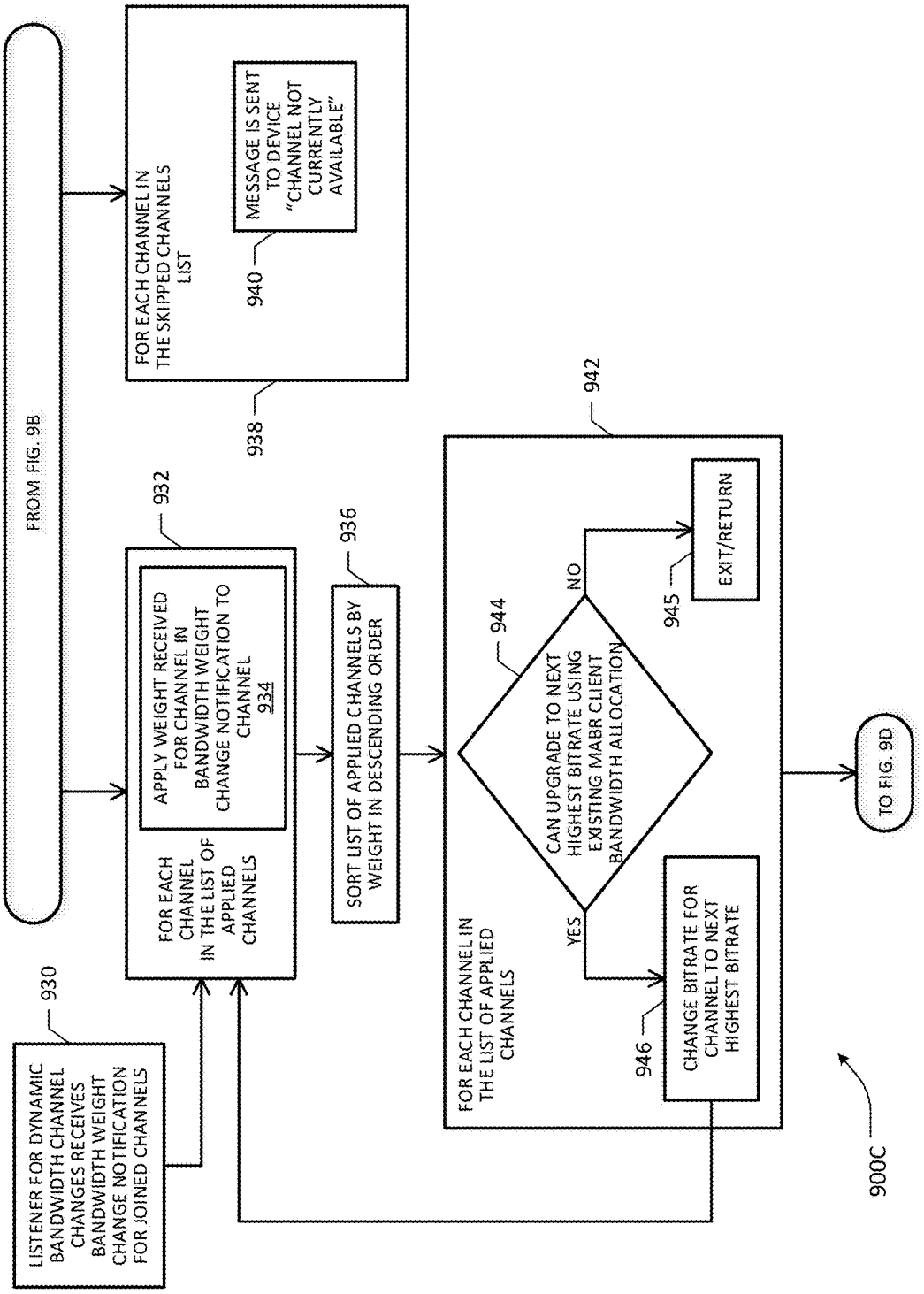

FROM FIG. 9B
930
LISTENER FOR DYNAMIC BANDWIDTH CHANNEL CHANGES RECEIVES BANDWIDTH WEIGHT CHANGE NOTIFICATION FOR JOINED CHANNELS
932
FOR EACH CHANNEL IN THE LIST OF APPLIED CHANNELS
APPLY WEIGHT RECEIVED FOR CHANNEL IN BANDWIDTH WEIGHT CHANGE NOTIFICATION TO CHANNEL 934
936
SORT LIST OF APPLIED CHANNELS BY WEIGHT IN DESCENDING ORDER
942
FOR EACH CHANNEL IN THE LIST OF APPLIED CHANNELS
944
CAN UPGRADE TO NEXT HIGHEST BITRATE USING EXISTING MABR CLIENT BANDWIDTH ALLOCATION
NO
945
EXIT/RETURN
YES
946
CHANGE BITRATE FOR CHANNEL TO NEXT HIGHEST BITRATE
TO FIG. 9D
938
FOR EACH CHANNEL IN THE SKIPPED CHANNELS LIST
940
MESSAGE IS SENT TO DEVICE "CHANNEL NOT CURRENTLY AVAILABLE"
900C

FIG. 9C

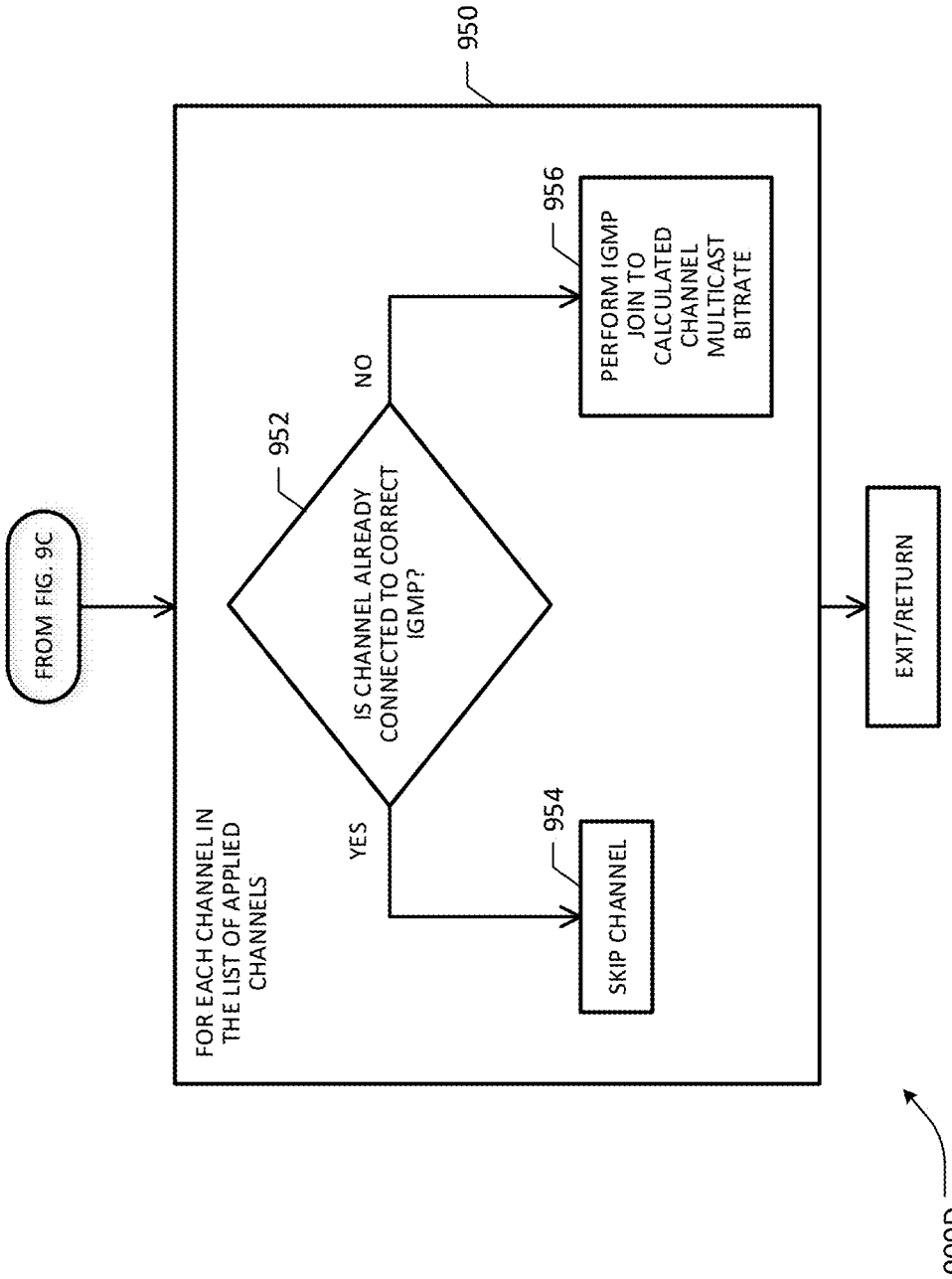

900D
950
FOR EACH CHANNEL IN THE LIST OF APPLIED CHANNELS
FROM FIG. 9C
952
IS CHANNEL ALREADY CONNECTED TO CORRECT IGMP?
NO
YES
956
PERFORM IGMP JOIN TO CALCULATED CHANNEL MULTICAST BITRATE
954
SKIP CHANNEL
EXIT/RETURN

FIG. 9D

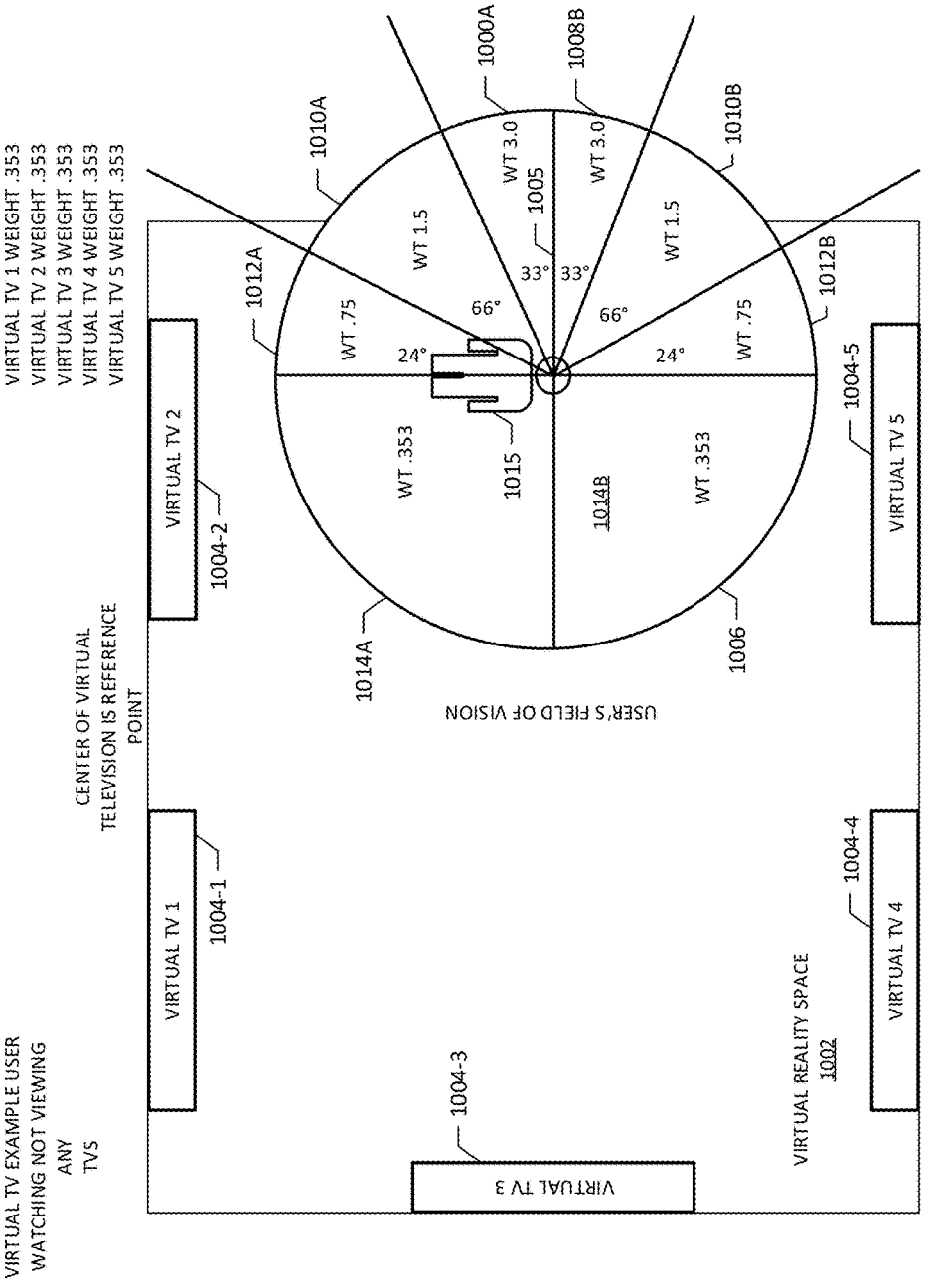

VIRTUAL TV EXAMPLE USER WATCHING NOT VIEWING ANY TVS
VIRTUAL TV 1 WEIGHT .353
VIRTUAL TV 2 WEIGHT .353
VIRTUAL TV 3 WEIGHT .353
VIRTUAL TV 4 WEIGHT .353
VIRTUAL TV 5 WEIGHT .353
CENTER OF VIRTUAL TELEVISION IS REFERENCE POINT
VIRTUAL TV 1
1004-1
VIRTUAL TV 2
1004-2
VIRTUAL TV 3
1004-3
VIRTUAL TV 4
1004-4
VIRTUAL TV 5
1004-5
VIRTUAL REALITY SPACE
1002
1000A
1010A
1010B
1012A
1012B
1014A
1014B
1015
1005
1006
1008B
WT .75
WT 1.5
WT 3.0
WT .353
24°
33°
66°
USER'S FIELD OF VISION

FIG. 10A

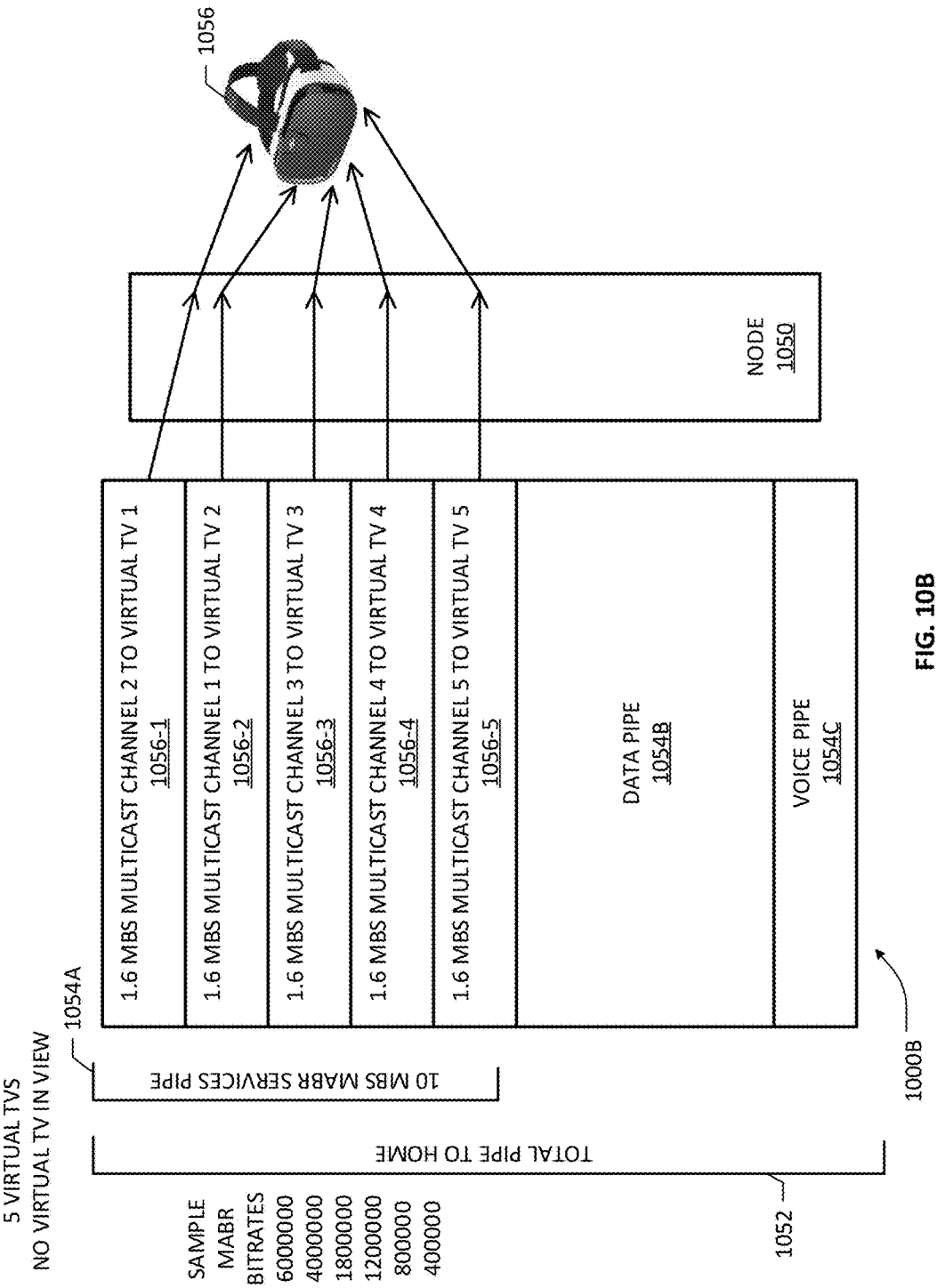

5 VIRTUAL TVS
NO VIRTUAL TV IN VIEW
SAMPLE MABR BITRATES
6000000
4000000
1800000
1200000
800000
400000
1052
TOTAL PIPE TO HOME
10 MBS MABR SERVICES PIPE
1054A
1000B
1.6 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 1
1056-1
1.6 MBS MULTICAST CHANNEL 1 TO VIRTUAL TV 2
1056-2
1.6 MBS MULTICAST CHANNEL 3 TO VIRTUAL TV 3
1056-3
1.6 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
1056-4
1.6 MBS MULTICAST CHANNEL 5 TO VIRTUAL TV 5
1056-5
DATA PIPE
1054B
VOICE PIPE
1054C
NODE
1050
1056

FIG. 10B

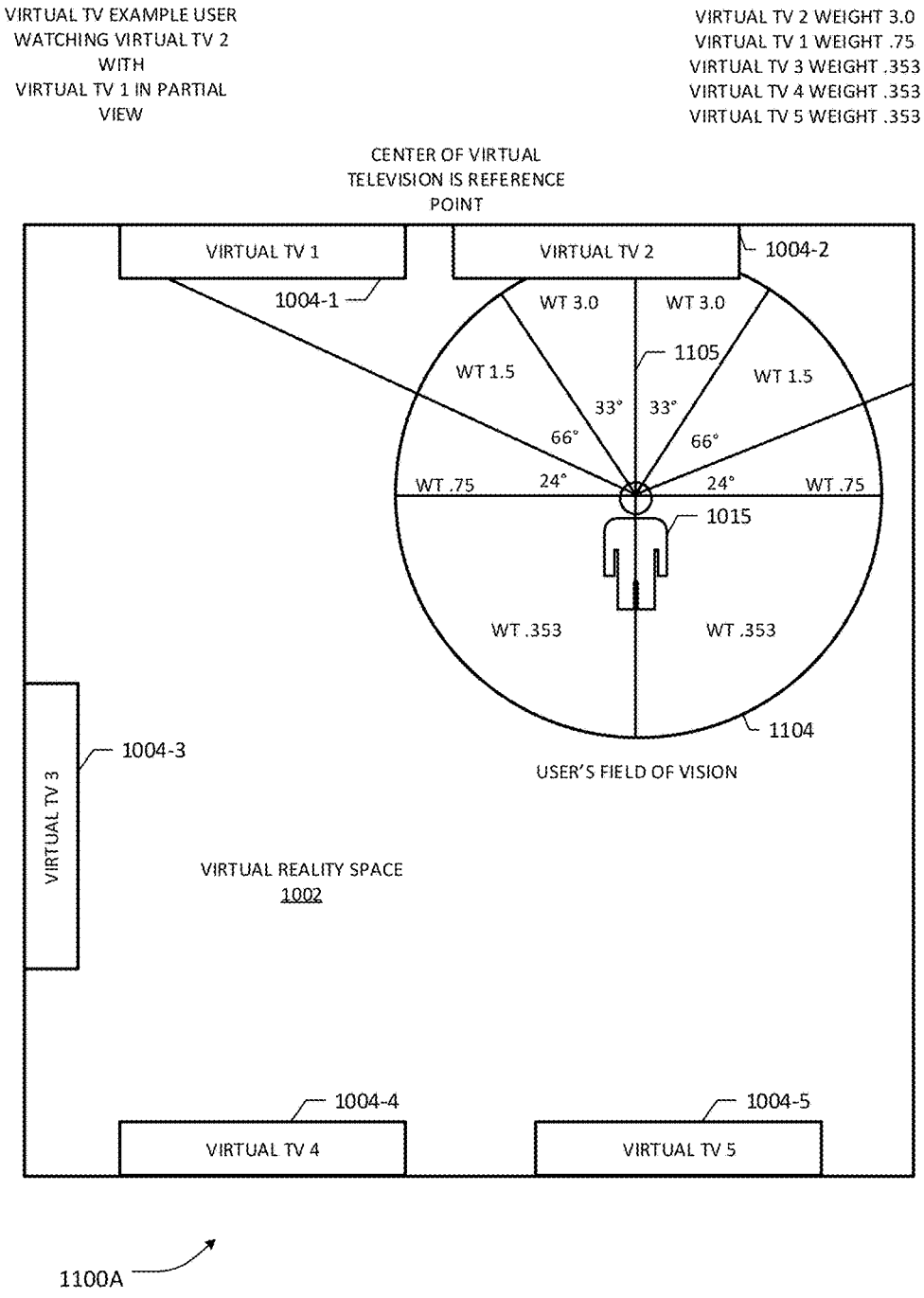

VIRTUAL TV EXAMPLE USER WATCHING VIRTUAL TV 2 WITH VIRTUAL TV 1 IN PARTIAL VIEW
VIRTUAL TV 2 WEIGHT 3.0
VIRTUAL TV 1 WEIGHT .75
VIRTUAL TV 3 WEIGHT .353
VIRTUAL TV 4 WEIGHT .353
VIRTUAL TV 5 WEIGHT .353
CENTER OF VIRTUAL TELEVISION IS REFERENCE POINT
VIRTUAL TV 1
VIRTUAL TV 2
1004-1
1004-2
WT 3.0
WT 3.0
1105
WT 1.5
WT 1.5
33°
33°
66°
66°
WT .75
24°
24°
WT .75
1015
WT .353
WT .353
1104
USER'S FIELD OF VISION
1004-3
VIRTUAL TV 3
VIRTUAL REALITY SPACE
1002
1004-4
1004-5
VIRTUAL TV 4
VIRTUAL TV 5
1100A

FIG. 11A

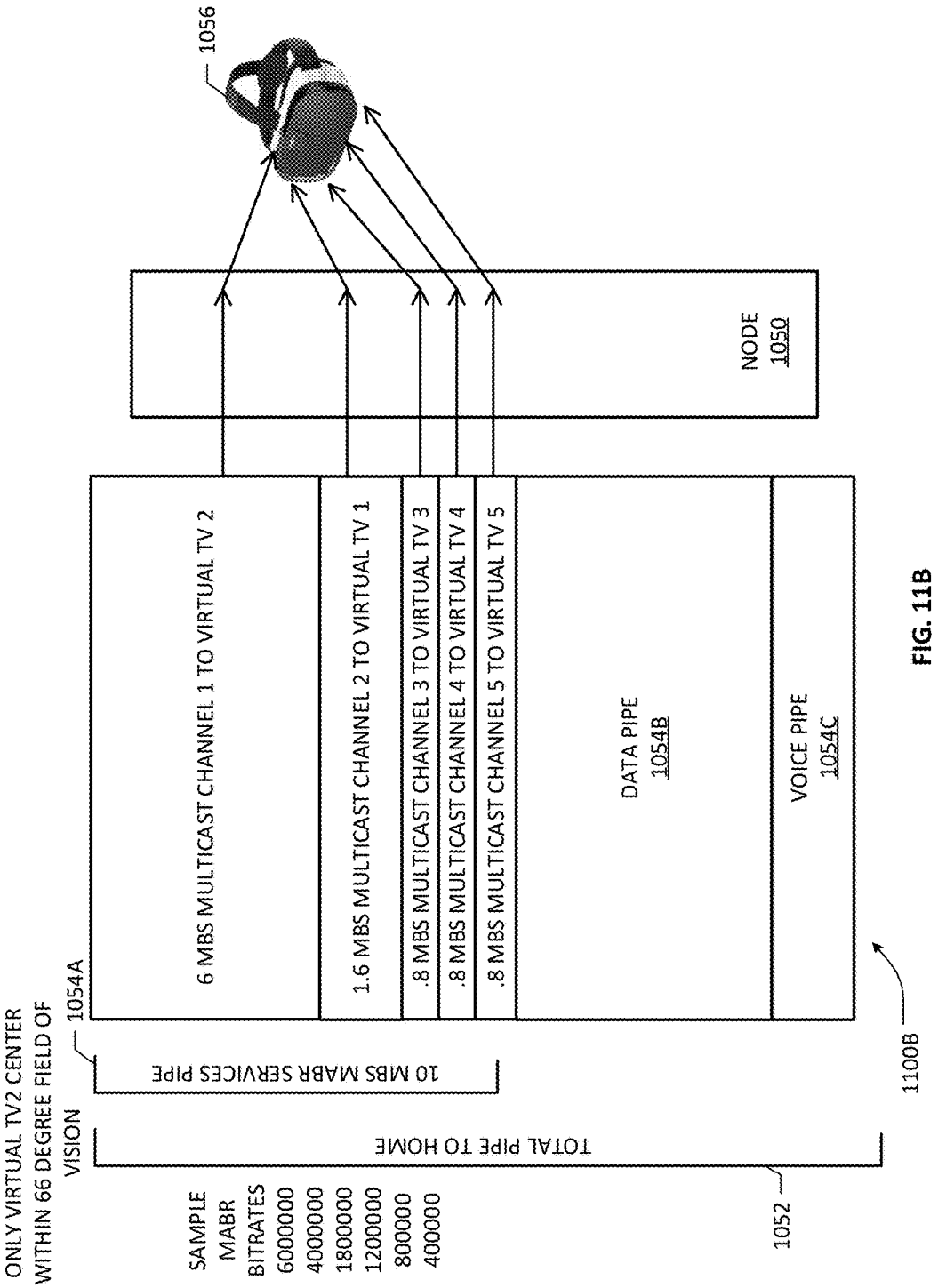

1056
NODE
1050
6 MBS MULTICAST CHANNEL 1 TO VIRTUAL TV 2
1.6 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 1
.8 MBS MULTICAST CHANNEL 3 TO VIRTUAL TV 3
.8 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
.8 MBS MULTICAST CHANNEL 5 TO VIRTUAL TV 5
DATA PIPE
1054B
VOICE PIPE
1054C
1100B
1054A
10 MBS MABR SERVICES PIPE
TOTAL PIPE TO HOME
1052
ONLY VIRTUAL TV2 CENTER
WITHIN 66 DEGREE FIELD OF
VISION
SAMPLE
MABR
BITRATES
6000000
4000000
1800000
1200000
800000
400000

FIG. 11B

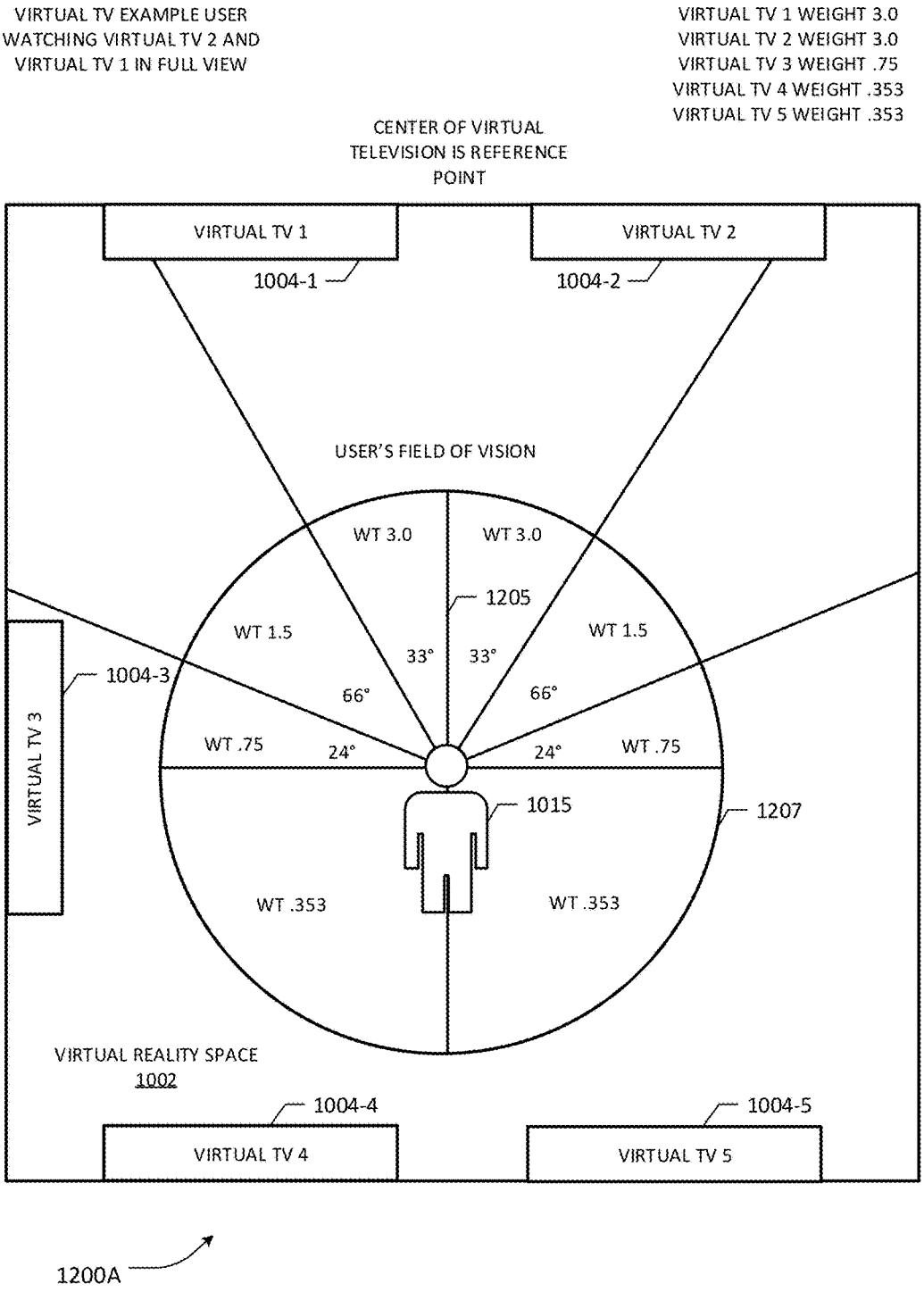

VIRTUAL TV EXAMPLE USER WATCHING VIRTUAL TV 2 AND VIRTUAL TV 1 IN FULL VIEW
VIRTUAL TV 1 WEIGHT 3.0
VIRTUAL TV 2 WEIGHT 3.0
VIRTUAL TV 3 WEIGHT .75
VIRTUAL TV 4 WEIGHT .353
VIRTUAL TV 5 WEIGHT .353
CENTER OF VIRTUAL TELEVISION IS REFERENCE POINT
VIRTUAL TV 1
VIRTUAL TV 2
1004-1
1004-2
USER'S FIELD OF VISION
WT 3.0
WT 3.0
1205
WT 1.5
WT 1.5
33°
33°
66°
66°
1004-3
VIRTUAL TV 3
WT .75
24°
24°
WT .75
1015
1207
WT .353
WT .353
VIRTUAL REALITY SPACE
1002
1004-4
1004-5
VIRTUAL TV 4
VIRTUAL TV 5
1200A

FIG. 12A

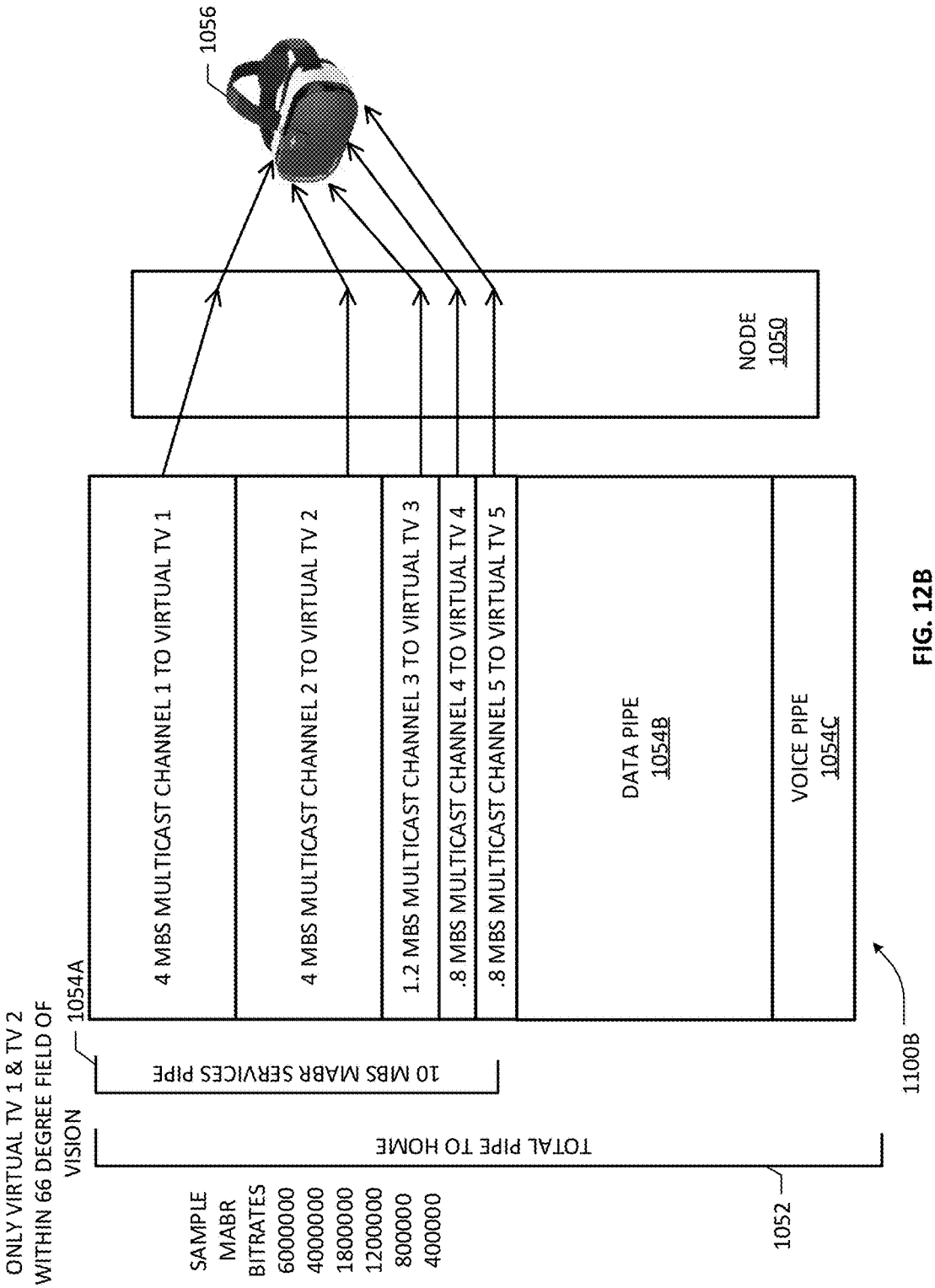

1056
NODE
1050
4 MBS MULTICAST CHANNEL 1 TO VIRTUAL TV 1
4 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 2
1.2 MBS MULTICAST CHANNEL 3 TO VIRTUAL TV 3
.8 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
.8 MBS MULTICAST CHANNEL 5 TO VIRTUAL TV 5
DATA PIPE
1054B
VOICE PIPE
1054C
1100B
1054A
10 MBS MABR SERVICES PIPE
TOTAL PIPE TO HOME
1052
ONLY VIRTUAL TV 1 & TV 2
WITHIN 66 DEGREE FIELD OF
VISION
SAMPLE
MABR
BITRATES
6000000
4000000
1800000
1200000
800000
400000

FIG. 12B

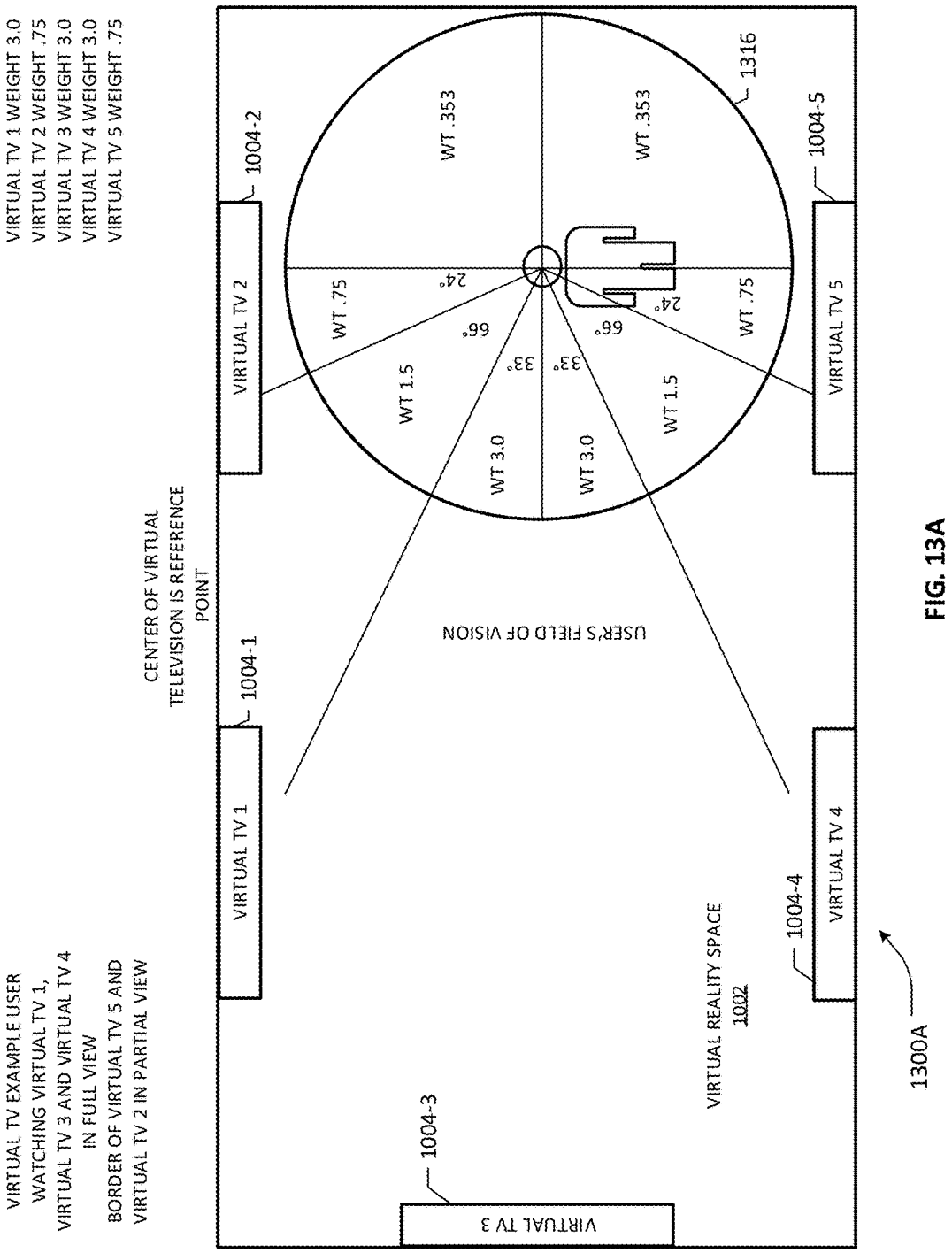

VIRTUAL TV 1 WEIGHT 3.0
VIRTUAL TV 2 WEIGHT .75
VIRTUAL TV 3 WEIGHT 3.0
VIRTUAL TV 4 WEIGHT 3.0
VIRTUAL TV 5 WEIGHT .75
VIRTUAL TV EXAMPLE USER WATCHING VIRTUAL TV 1, VIRTUAL TV 3 AND VIRTUAL TV 4 IN FULL VIEW
BORDER OF VIRTUAL TV 5 AND VIRTUAL TV 2 IN PARTIAL VIEW
CENTER OF VIRTUAL TELEVISION IS REFERENCE POINT
1004-1
VIRTUAL TV 1
1004-2
VIRTUAL TV 2
1004-3
VIRTUAL TV 3
1004-4
VIRTUAL TV 4
1004-5
VIRTUAL TV 5
1316
WT .353
WT .353
WT .75
WT .75
WT 1.5
WT 1.5
WT 3.0
WT 3.0
24°
24°
66°
66°
33°
33°
USER'S FIELD OF VISION
VIRTUAL REALITY SPACE
1002
1300A

FIG. 13A

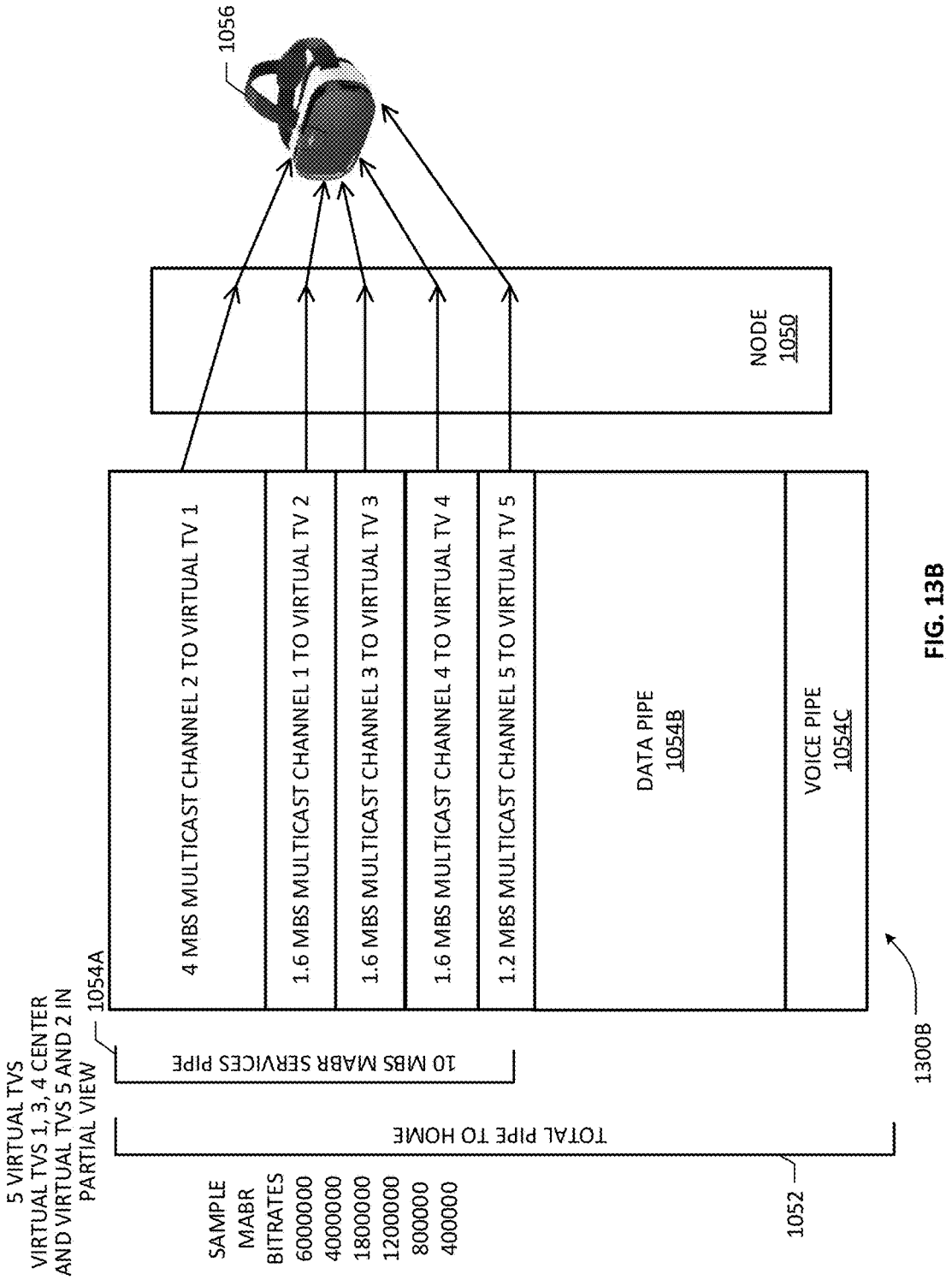

1056
NODE
1050
4 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 1
1.6 MBS MULTICAST CHANNEL 1 TO VIRTUAL TV 2
1.6 MBS MULTICAST CHANNEL 3 TO VIRTUAL TV 3
1.6 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
1.2 MBS MULTICAST CHANNEL 5 TO VIRTUAL TV 5
DATA PIPE
1054B
VOICE PIPE
1054C
1054A
10 MBS MABR SERVICES PIPE
TOTAL PIPE TO HOME
1300B
1052
5 VIRTUAL TVS
VIRTUAL TVS 1, 3, 4 CENTER
AND VIRTUAL TVS 5 AND 2 IN
PARTIAL VIEW
SAMPLE
MABR
BITRATES
6000000
4000000
1800000
1200000
800000
400000

FIG. 13B

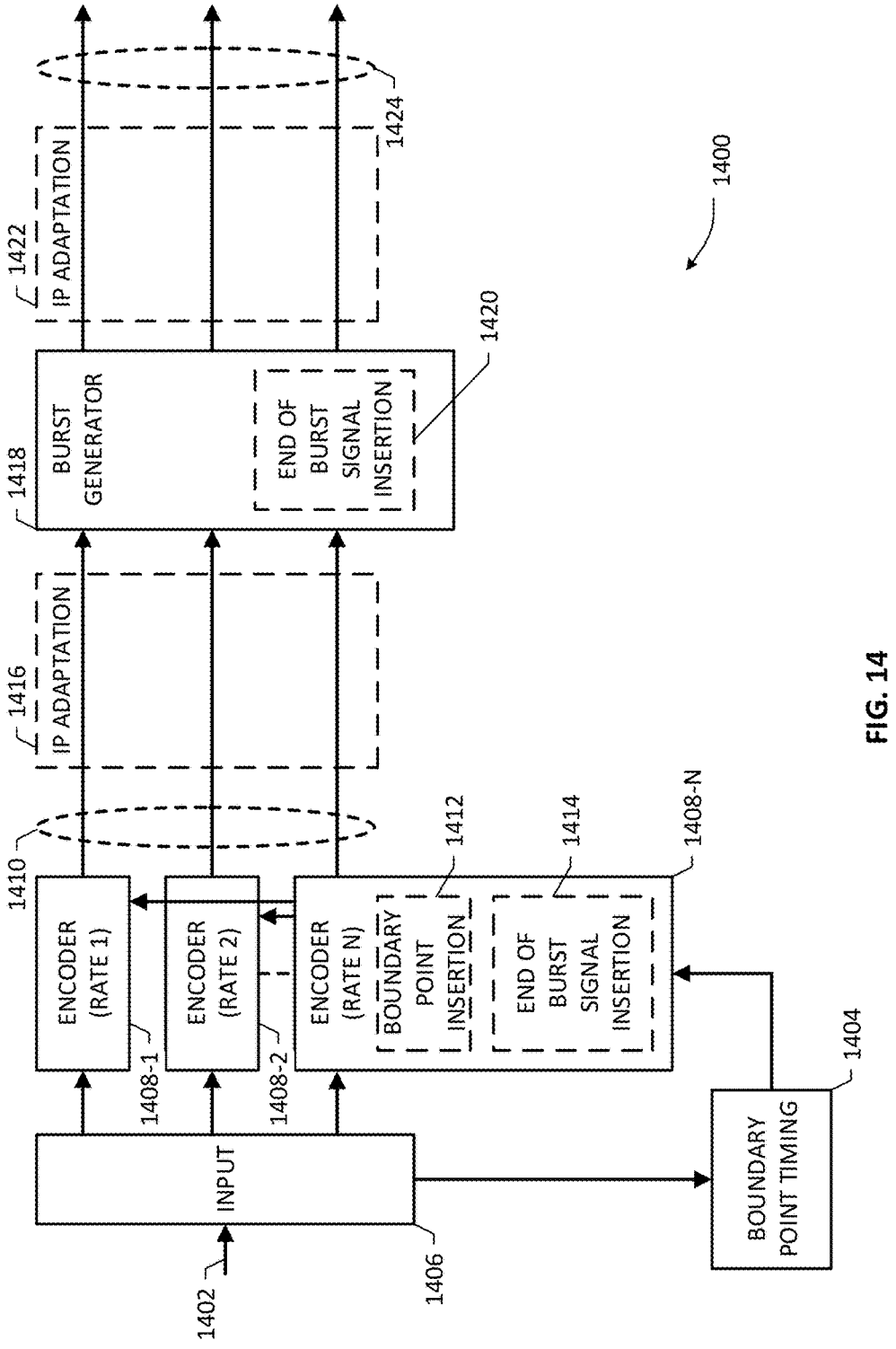

1400
1402
INPUT
1406
1404
BOUNDARY POINT TIMING
1408-1
1408-2
1408-N
ENCODER (RATE 1)
ENCODER (RATE 2)
ENCODER (RATE N)
1410
1412
BOUNDARY POINT INSERTION
1414
END OF BURST SIGNAL INSERTION
1416
IP ADAPTATION
1418
BURST GENERATOR
1420
END OF BURST SIGNAL INSERTION
1422
IP ADAPTATION
1424

FIG. 14

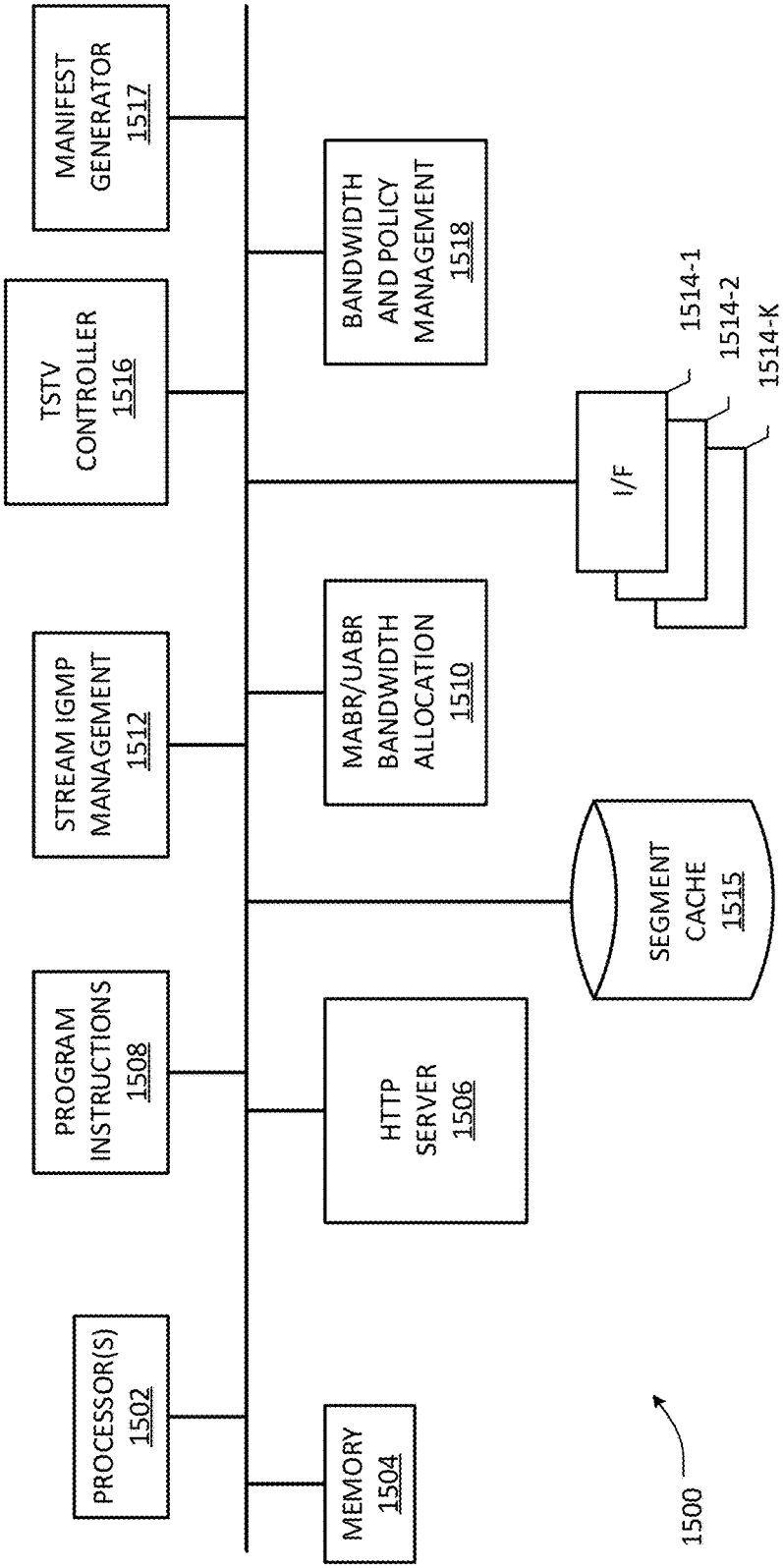

MANIFEST GENERATOR 1517
TSTV CONTROLLER 1516
STREAM IGMP MANAGEMENT 1512
PROGRAM INSTRUCTIONS 1508
PROCESSOR(S) 1502
MEMORY 1504
HTTP SERVER 1506
MABR/UABR BANDWIDTH ALLOCATION 1510
BANDWIDTH AND POLICY MANAGEMENT 1518
I/F
1514-1
1514-2
1514-K
SEGMENT CACHE 1515
1500

FIG. 15

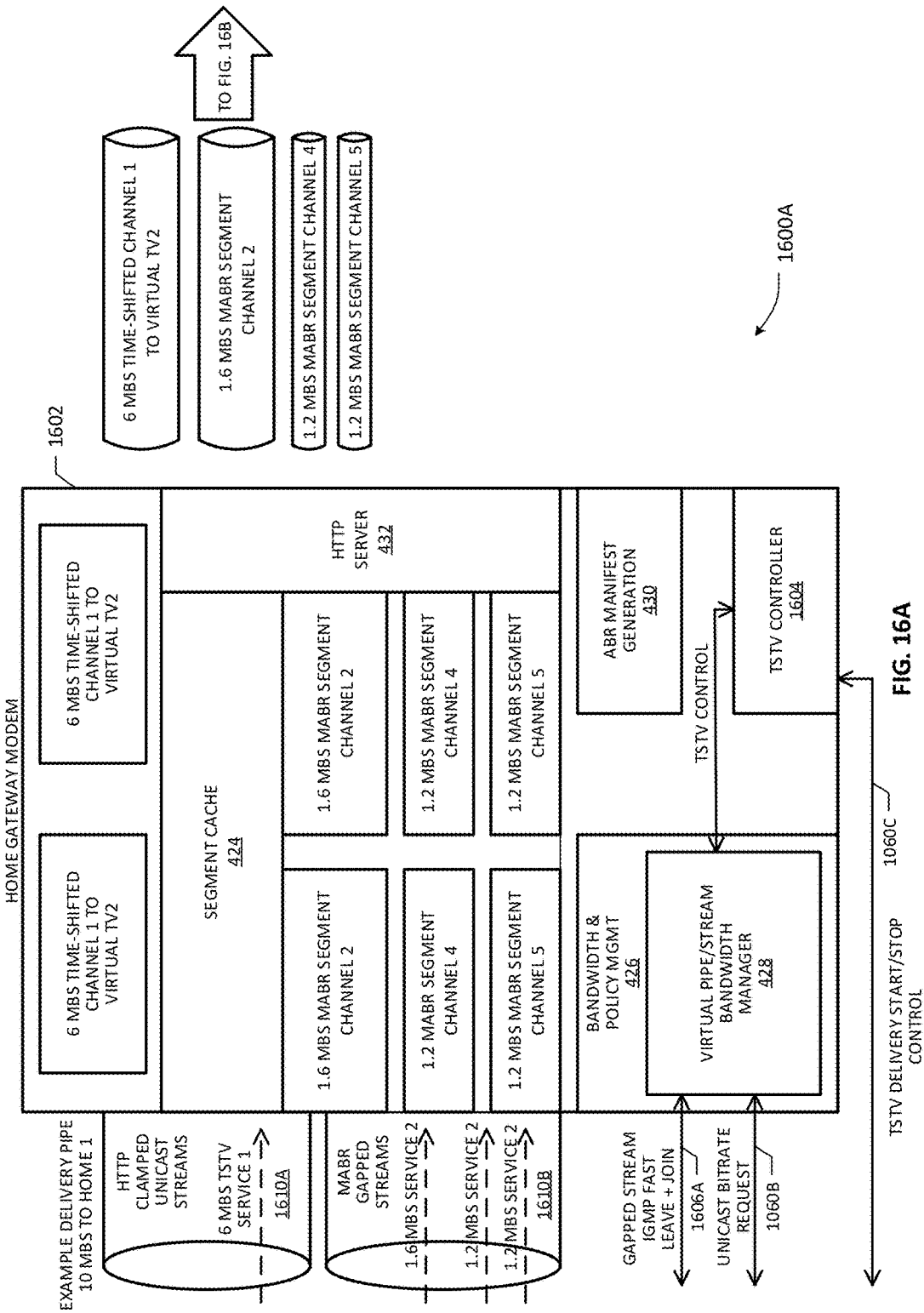

1600A
1602
HOME GATEWAY MODEM
6 MBS TIME-SHIFTED CHANNEL 1 TO VIRTUAL TV2
1.6 MBS MABR SEGMENT CHANNEL 2
1.2 MBS MABR SEGMENT CHANNEL 4
1.2 MBS MABR SEGMENT CHANNEL 5
TO FIG. 16B
6 MBS TIME-SHIFTED CHANNEL 1 TO VIRTUAL TV2
SEGMENT CACHE 424
HTTP SERVER 432
1.6 MBS MABR SEGMENT CHANNEL 2
1.2 MBS MABR SEGMENT CHANNEL 4
1.2 MBS MABR SEGMENT CHANNEL 5
ABR MANIFEST GENERATION 430
TSTV CONTROL
TSTV CONTROLLER 1604
BANDWIDTH & POLICY MGMT 426
VIRTUAL PIPE/STREAM BANDWIDTH MANAGER 428
1060C
TSTV DELIVERY START/STOP CONTROL
EXAMPLE DELIVERY PIPE 10 MBS TO HOME 1
HTTP CLAMPED UNICAST STREAMS
6 MBS TSTV SERVICE 1 1610A
MABR GAPPED STREAMS
1.6 MBS SERVICE 2
1.2 MBS SERVICE 2
1.2 MBS SERVICE 2 1610B
GAPPED STREAM IGMP FAST LEAVE + JOIN 1606A
UNICAST BITRATE REQUEST 1060B

FIG. 16A

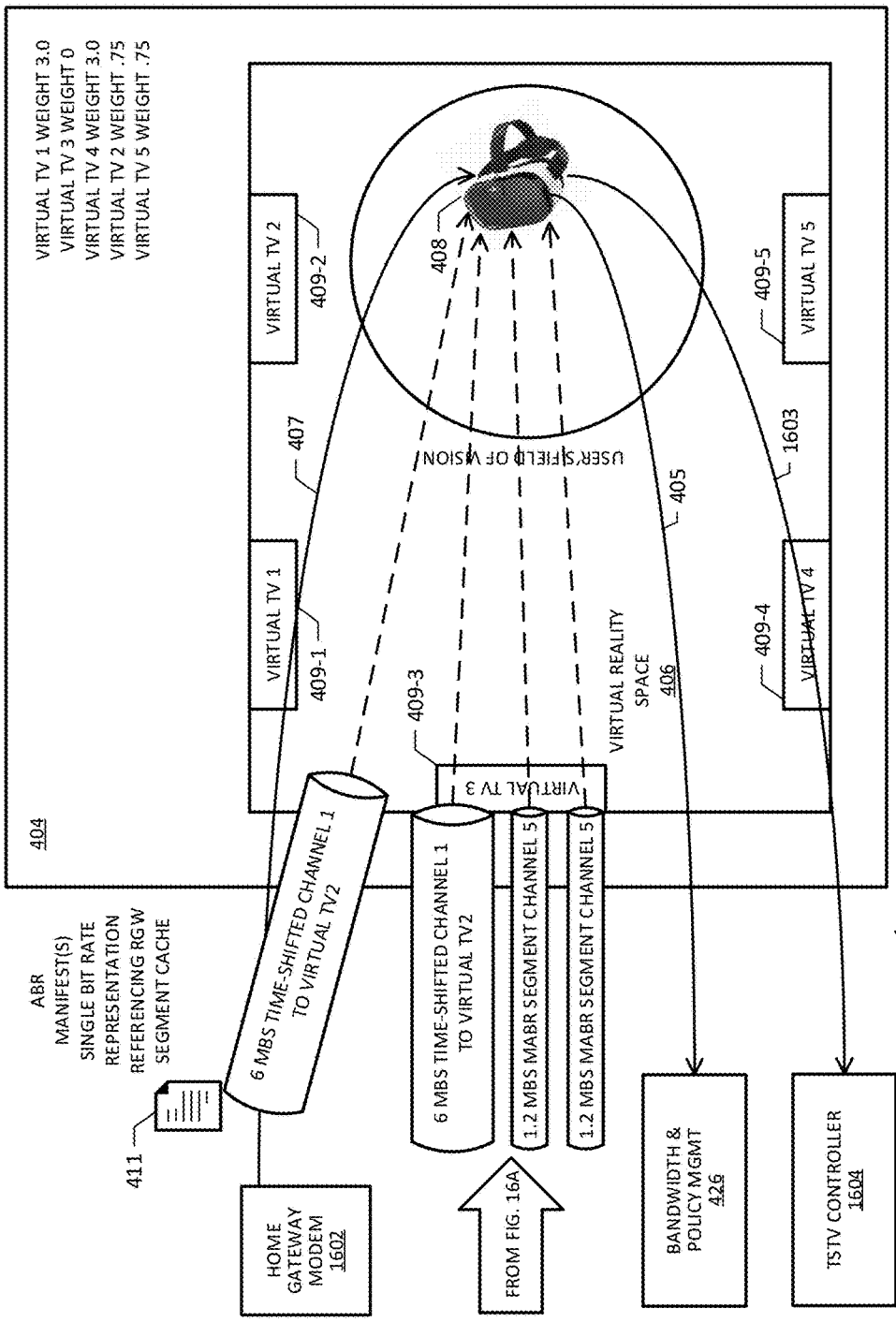

VIRTUAL TV 1 WEIGHT 3.0
VIRTUAL TV 3 WEIGHT 0
VIRTUAL TV 4 WEIGHT 3.0
VIRTUAL TV 2 WEIGHT .75
VIRTUAL TV 5 WEIGHT .75
404
VIRTUAL TV 1
409-1
VIRTUAL TV 2
409-2
VIRTUAL TV 3
409-3
VIRTUAL TV 4
409-4
VIRTUAL TV 5
409-5
407
408
USER'S FIELD OF VISION
405
1603
VIRTUAL REALITY SPACE 406
6 MBS TIME-SHIFTED CHANNEL 1 TO VIRTUAL TV2
6 MBS TIME-SHIFTED CHANNEL 1 TO VIRTUAL TV2
1.2 MBS MABR SEGMENT CHANNEL 5
1.2 MBS MABR SEGMENT CHANNEL 5
ABR MANIFEST(S) SINGLE BIT RATE REPRESENTATION REFERENCING RGW SEGMENT CACHE
411
HOME GATEWAY MODEM 1602
FROM FIG. 16A
BANDWIDTH & POLICY MGMT 426
TSTV CONTROLLER 1604
1600B

FIG. 16B

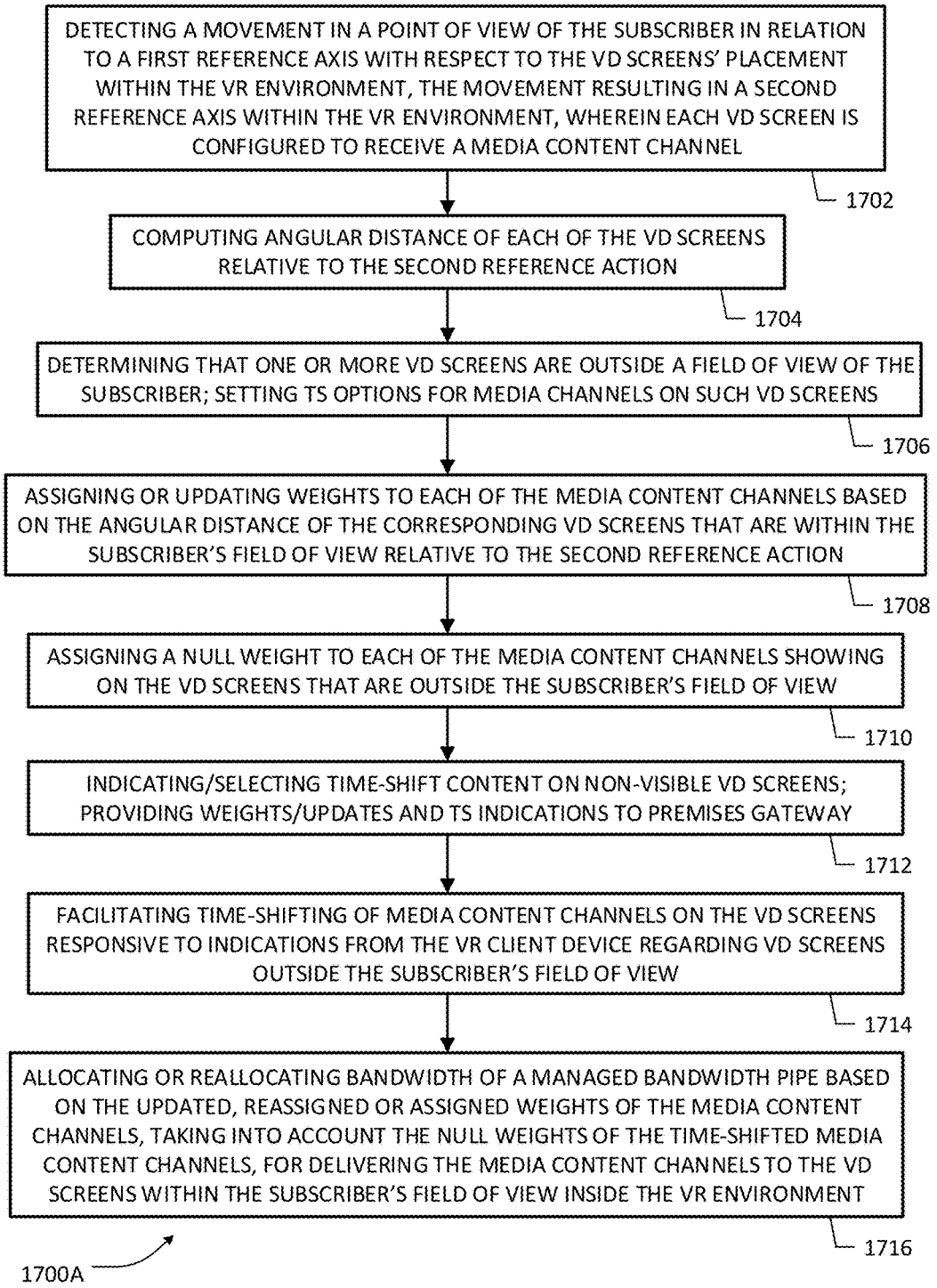

DETECTING A MOVEMENT IN A POINT OF VIEW OF THE SUBSCRIBER IN RELATION TO A FIRST REFERENCE AXIS WITH RESPECT TO THE VD SCREENS' PLACEMENT WITHIN THE VR ENVIRONMENT, THE MOVEMENT RESULTING IN A SECOND REFERENCE AXIS WITHIN THE VR ENVIRONMENT, WHEREIN EACH VD SCREEN IS CONFIGURED TO RECEIVE A MEDIA CONTENT CHANNEL
1702
COMPUTING ANGULAR DISTANCE OF EACH OF THE VD SCREENS RELATIVE TO THE SECOND REFERENCE ACTION
1704
DETERMINING THAT ONE OR MORE VD SCREENS ARE OUTSIDE A FIELD OF VIEW OF THE SUBSCRIBER; SETTING TS OPTIONS FOR MEDIA CHANNELS ON SUCH VD SCREENS
1706
ASSIGNING OR UPDATING WEIGHTS TO EACH OF THE MEDIA CONTENT CHANNELS BASED ON THE ANGULAR DISTANCE OF THE CORRESPONDING VD SCREENS THAT ARE WITHIN THE SUBSCRIBER'S FIELD OF VIEW RELATIVE TO THE SECOND REFERENCE ACTION
1708
ASSIGNING A NULL WEIGHT TO EACH OF THE MEDIA CONTENT CHANNELS SHOWING ON THE VD SCREENS THAT ARE OUTSIDE THE SUBSCRIBER'S FIELD OF VIEW
1710
INDICATING/SELECTING TIME-SHIFT CONTENT ON NON-VISIBLE VD SCREENS; PROVIDING WEIGHTS/UPDATES AND TS INDICATIONS TO PREMISES GATEWAY
1712
FACILITATING TIME-SHIFTING OF MEDIA CONTENT CHANNELS ON THE VD SCREENS RESPONSIVE TO INDICATIONS FROM THE VR CLIENT DEVICE REGARDING VD SCREENS OUTSIDE THE SUBSCRIBER'S FIELD OF VIEW
1714
ALLOCATING OR REALLOCATING BANDWIDTH OF A MANAGED BANDWIDTH PIPE BASED ON THE UPDATED, REASSIGNED OR ASSIGNED WEIGHTS OF THE MEDIA CONTENT CHANNELS, TAKING INTO ACCOUNT THE NULL WEIGHTS OF THE TIME-SHIFTED MEDIA CONTENT CHANNELS, FOR DELIVERING THE MEDIA CONTENT CHANNELS TO THE VD SCREENS WITHIN THE SUBSCRIBER'S FIELD OF VIEW INSIDE THE VR ENVIRONMENT
1716
1700A

FIG. 17A

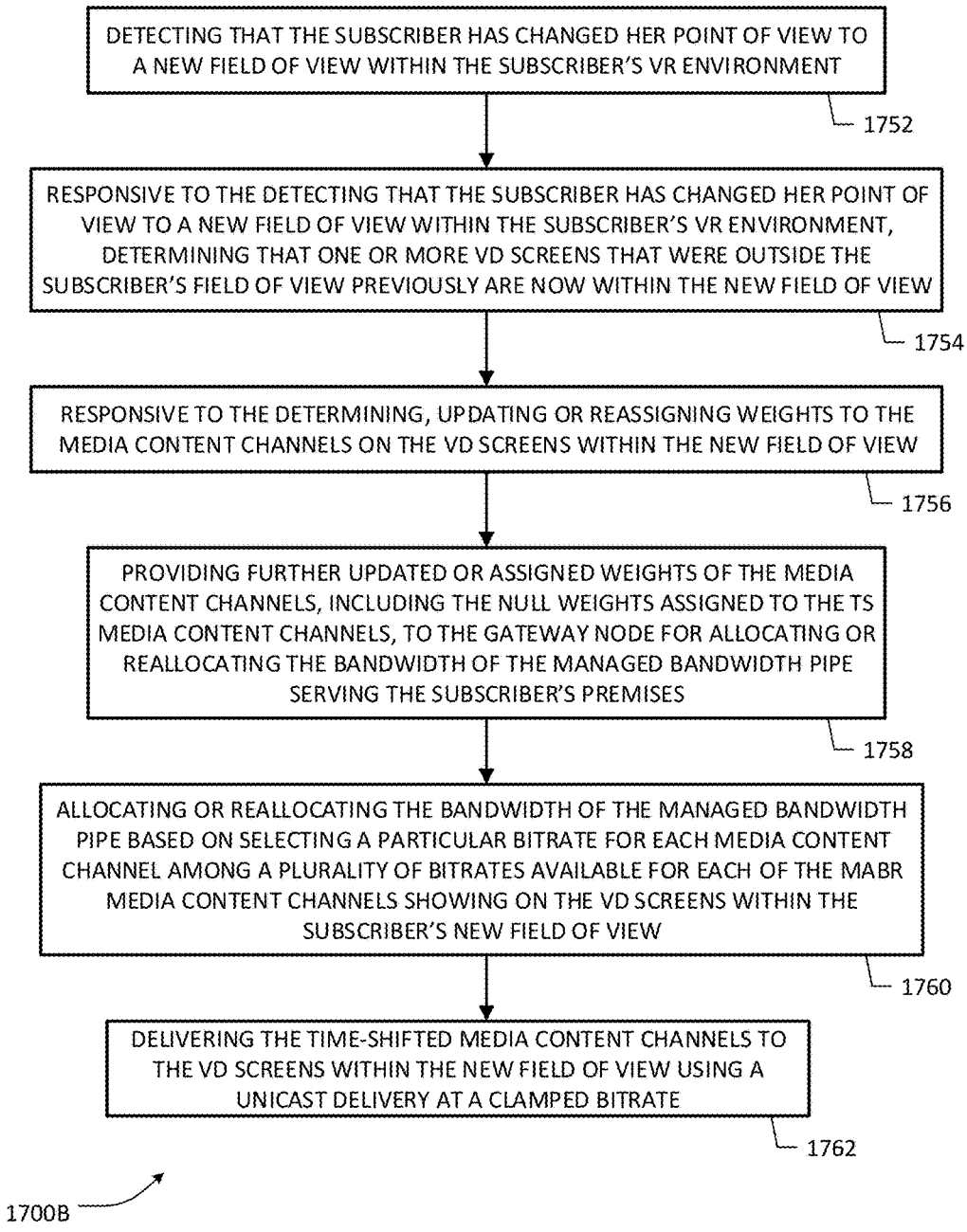

DETECTING THAT THE SUBSCRIBER HAS CHANGED HER POINT OF VIEW TO A NEW FIELD OF VIEW WITHIN THE SUBSCRIBER'S VR ENVIRONMENT
1752
RESPONSIVE TO THE DETECTING THAT THE SUBSCRIBER HAS CHANGED HER POINT OF VIEW TO A NEW FIELD OF VIEW WITHIN THE SUBSCRIBER'S VR ENVIRONMENT, DETERMINING THAT ONE OR MORE VD SCREENS THAT WERE OUTSIDE THE SUBSCRIBER'S FIELD OF VIEW PREVIOUSLY ARE NOW WITHIN THE NEW FIELD OF VIEW
1754
RESPONSIVE TO THE DETERMINING, UPDATING OR REASSIGNING WEIGHTS TO THE MEDIA CONTENT CHANNELS ON THE VD SCREENS WITHIN THE NEW FIELD OF VIEW
1756
PROVIDING FURTHER UPDATED OR ASSIGNED WEIGHTS OF THE MEDIA CONTENT CHANNELS, INCLUDING THE NULL WEIGHTS ASSIGNED TO THE TS MEDIA CONTENT CHANNELS, TO THE GATEWAY NODE FOR ALLOCATING OR REALLOCATING THE BANDWIDTH OF THE MANAGED BANDWIDTH PIPE SERVING THE SUBSCRIBER'S PREMISES
1758
ALLOCATING OR REALLOCATING THE BANDWIDTH OF THE MANAGED BANDWIDTH PIPE BASED ON SELECTING A PARTICULAR BITRATE FOR EACH MEDIA CONTENT CHANNEL AMONG A PLURALITY OF BITRATES AVAILABLE FOR EACH OF THE MABR MEDIA CONTENT CHANNELS SHOWING ON THE VD SCREENS WITHIN THE SUBSCRIBER'S NEW FIELD OF VIEW
1760
DELIVERING THE TIME-SHIFTED MEDIA CONTENT CHANNELS TO THE VD SCREENS WITHIN THE NEW FIELD OF VIEW USING A UNICAST DELIVERY AT A CLAMPED BITRATE
1762
1700B

FIG. 17B

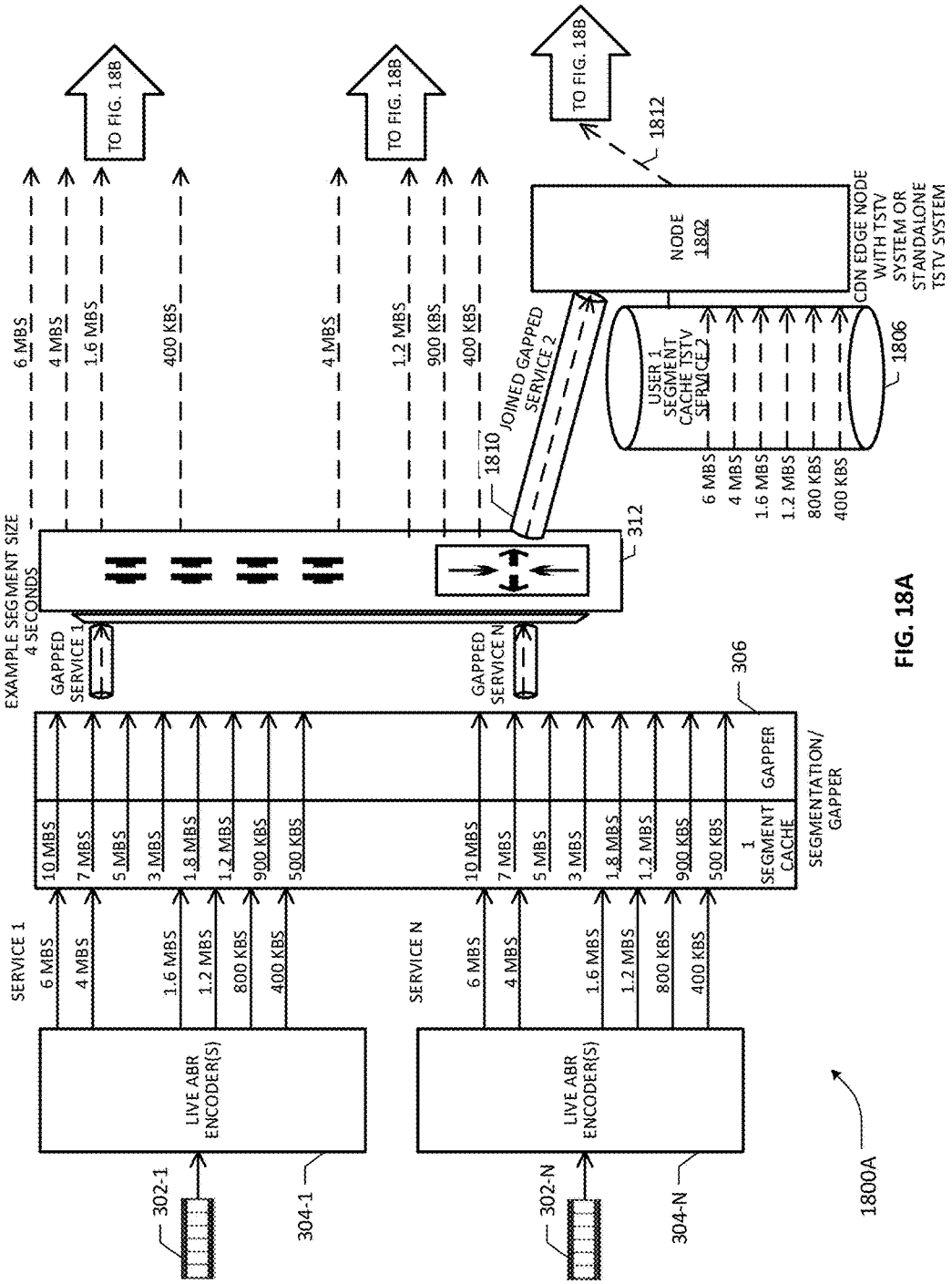

1800A
SERVICE 1
6 MBS
4 MBS
1.6 MBS
1.2 MBS
800 KBS
400 KBS
LIVE ABR ENCODER(S)
302-1
304-1
SERVICE N
6 MBS
4 MBS
1.6 MBS
1.2 MBS
800 KBS
400 KBS
LIVE ABR ENCODER(S)
302-N
304-N
306
10 MBS
7 MBS
5 MBS
3 MBS
1.8 MBS
1.2 MBS
900 KBS
500 KBS
1 SEGMENT CACHE
GAPPER
SEGMENTATION/ GAPPER
EXAMPLE SEGMENT SIZE 4 SECONDS
GAPPED SERVICE 1
GAPPED SERVICE N
312
1810
JOINED GAPPED SERVICE 2
1812
NODE 1802
CDN EDGE NODE WITH TSTV SYSTEM OR STANDALONE TSTV SYSTEM
USER 1 SEGMENT CACHE TSTV SERVICE 2
1806
6 MBS
4 MBS
1.6 MBS
1.2 MBS
800 KBS
400 KBS
TO FIG. 18B
TO FIG. 18B
TO FIG. 18B

FIG. 18A

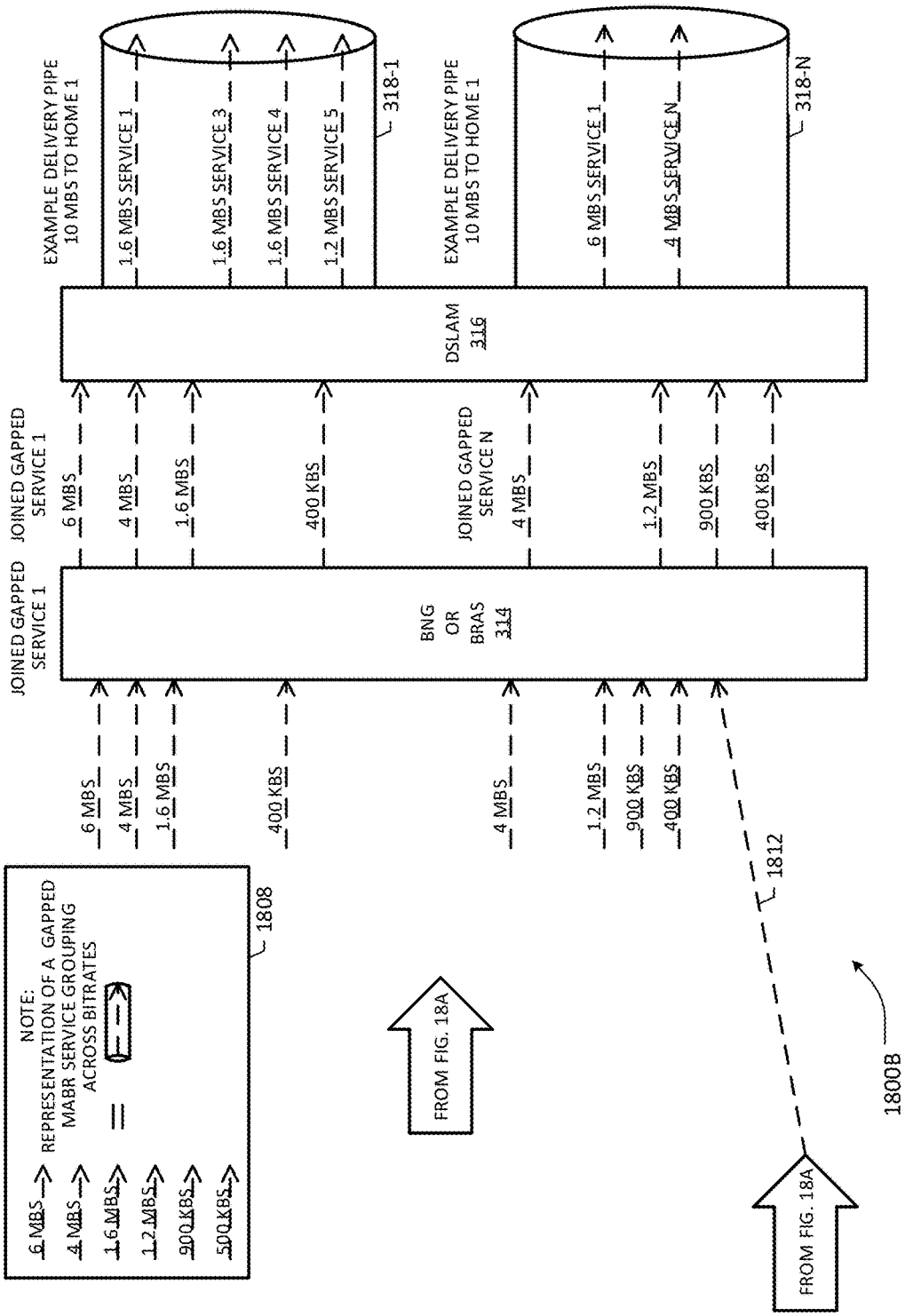

EXAMPLE DELIVERY PIPE
10 MBS TO HOME 1
1.6 MBS SERVICE 1
1.6 MBS SERVICE 3
1.6 MBS SERVICE 4
1.2 MBS SERVICE 5
318-1
EXAMPLE DELIVERY PIPE
10 MBS TO HOME 1
6 MBS SERVICE 1
4 MBS SERVICE N
318-N
DSLAM
316
JOINED GAPPED
SERVICE 1
6 MBS
4 MBS
1.6 MBS
400 KBS
JOINED GAPPED
SERVICE N
4 MBS
1.2 MBS
900 KBS
400 KBS
BNG
OR
BRAS
314
JOINED GAPPED
SERVICE 1
6 MBS
4 MBS
1.6 MBS
400 KBS
4 MBS
1.2 MBS
900 KBS
400 KBS
1812
1808
NOTE:
REPRESENTATION OF A GAPPED
MABR SERVICE GROUPING
ACROSS BITRATES
6 MBS
4 MBS
1.6 MBS
1.2 MBS
900 KBS
500 KBS
FROM FIG. 18A
FROM FIG. 18A
1800B

FIG. 18B

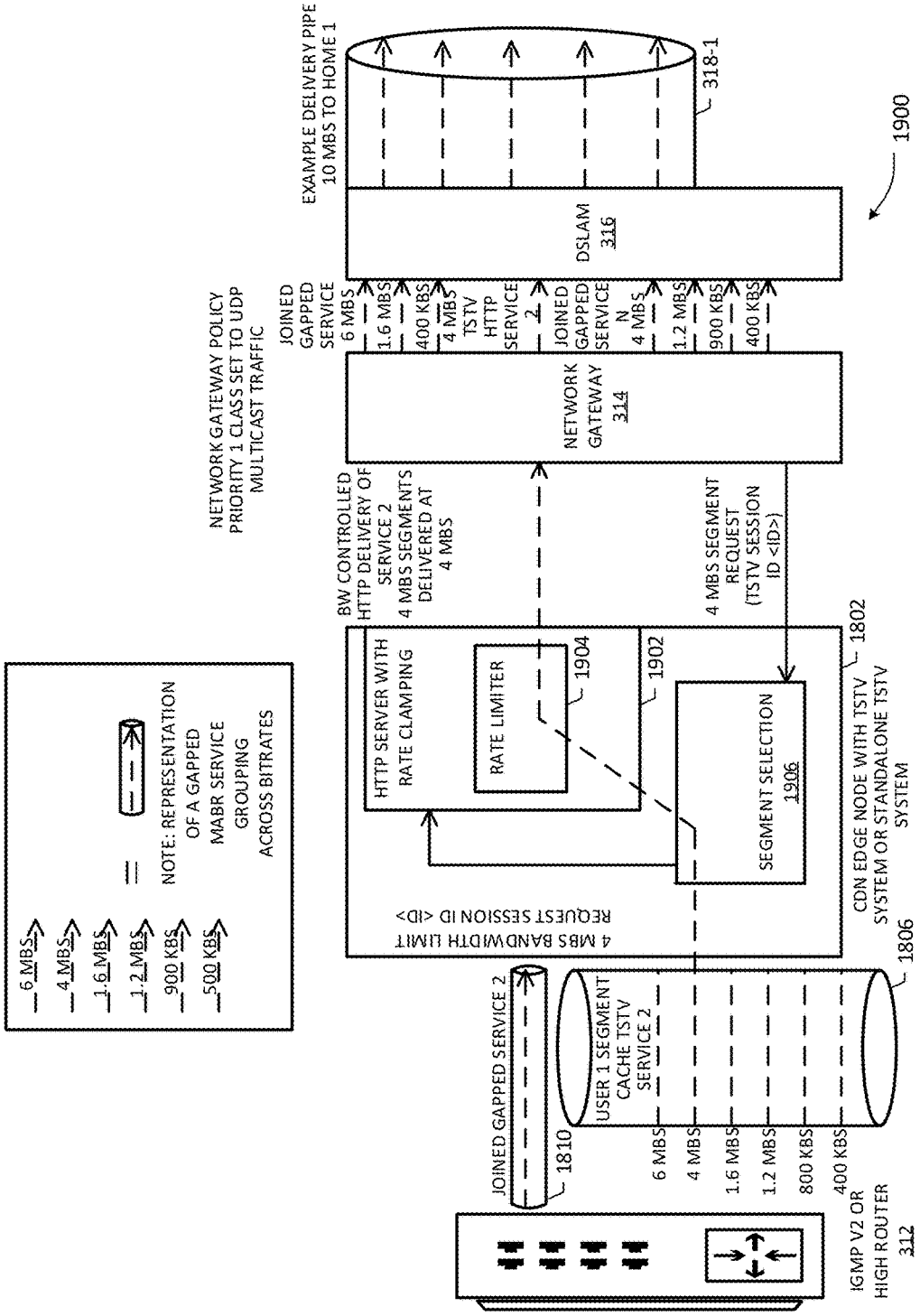

EXAMPLE DELIVERY PIPE
10 MBS TO HOME 1
318-1
1900
DSLAM
316
JOINED GAPPED SERVICE 6 MBS
1.6 MBS
400 KBS
4 MBS TSTV HTTP SERVICE 2
JOINED GAPPED SERVICE N 4 MBS
1.2 MBS
900 KBS
400 KBS
NETWORK GATEWAY
314
NETWORK GATEWAY POLICY
PRIORITY 1 CLASS SET TO UDP
MULTICAST TRAFFIC
BW CONTROLLED HTTP DELIVERY OF SERVICE 2 4 MBS SEGMENTS DELIVERED AT 4 MBS
4 MBS SEGMENT REQUEST (TSTV SESSION ID <ID>)
HTTP SERVER WITH RATE CLAMPING
RATE LIMITER
1904
1902
SEGMENT SELECTION
1906
4 MBS BANDWIDTH LIMIT REQUEST SESSION ID <ID>
CDN EDGE NODE WITH TSTV SYSTEM OR STANDALONE TSTV SYSTEM
1802
1806
JOINED GAPPED SERVICE 2
1810
USER 1 SEGMENT CACHE TSTV SERVICE 2
6 MBS
4 MBS
1.6 MBS
1.2 MBS
800 KBS
400 KBS
IGMP V2 OR HIGH ROUTER
312
6 MBS
4 MBS
1.6 MBS
1.2 MBS
900 KBS
500 KBS
NOTE: REPRESENTATION OF A GAPPED MABR SERVICE GROUPING ACROSS BITRATES

FIG. 19

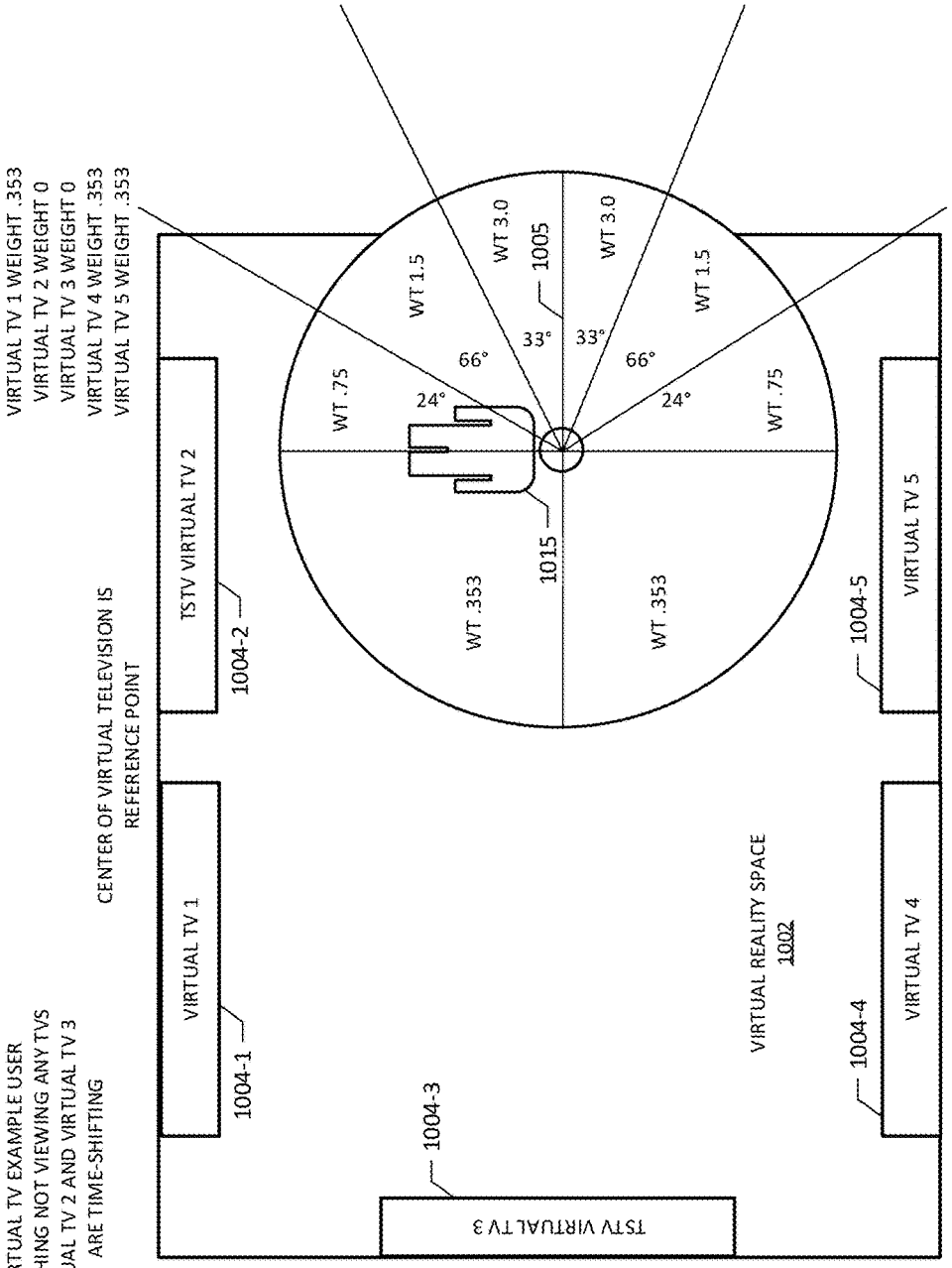

VIRTUAL TV 1 WEIGHT .353
VIRTUAL TV 2 WEIGHT 0
VIRTUAL TV 3 WEIGHT 0
VIRTUAL TV 4 WEIGHT .353
VIRTUAL TV 5 WEIGHT .353
VIRTUAL TV EXAMPLE USER WATCHING NOT VIEWING ANY TVS VIRTUAL TV 2 AND VIRTUAL TV 3 ARE TIME-SHIFTING
CENTER OF VIRTUAL TELEVISION IS REFERENCE POINT
VIRTUAL REALITY SPACE 1002
TSTV VIRTUAL TV 2
VIRTUAL TV 1
VIRTUAL TV 5
VIRTUAL TV 4
TSTV VIRTUAL TV 3
1004-1
1004-2
1004-3
1004-4
1004-5
2000A
1005
1015
WT .75
WT 1.5
WT 3.0
WT .353
66°
33°
24°

FIG. 20A

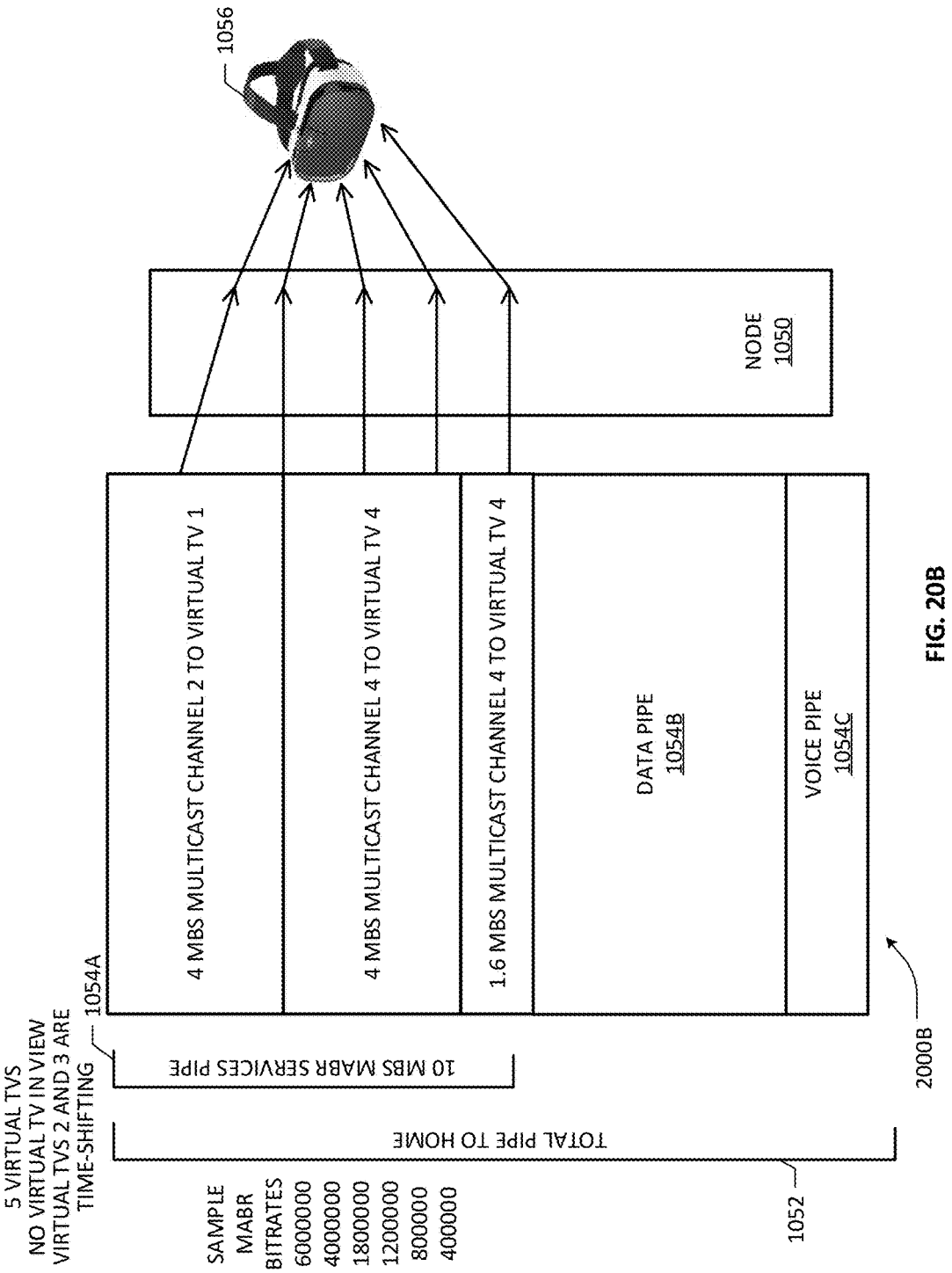

1056
NODE
1050
4 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 1
4 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
1.6 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
DATA PIPE
1054B
VOICE PIPE
1054C
2000B
1054A
10 MBS MABR SERVICES PIPE
TOTAL PIPE TO HOME
1052
5 VIRTUAL TVS
NO VIRTUAL TV IN VIEW
VIRTUAL TVS 2 AND 3 ARE
TIME-SHIFTING
SAMPLE
MABR
BITRATES
6000000
4000000
1800000
1200000
800000
400000

FIG. 20B

VIRTUAL TV EXAMPLE USER
WATCHING VIRTUAL TV 2 WITH
VIRTUAL TV 1 IN PARTIAL VIEW
VIRTUAL TV 3 IS TIME-SHIFTING

VIRTUAL TV 1 WEIGHT .75
VIRTUAL TV 2 WEIGHT 3.0
VIRTUAL TV 3 WEIGHT 0
VIRTUAL TV 4 WEIGHT .353
VIRTUAL TV 5 WEIGHT .353

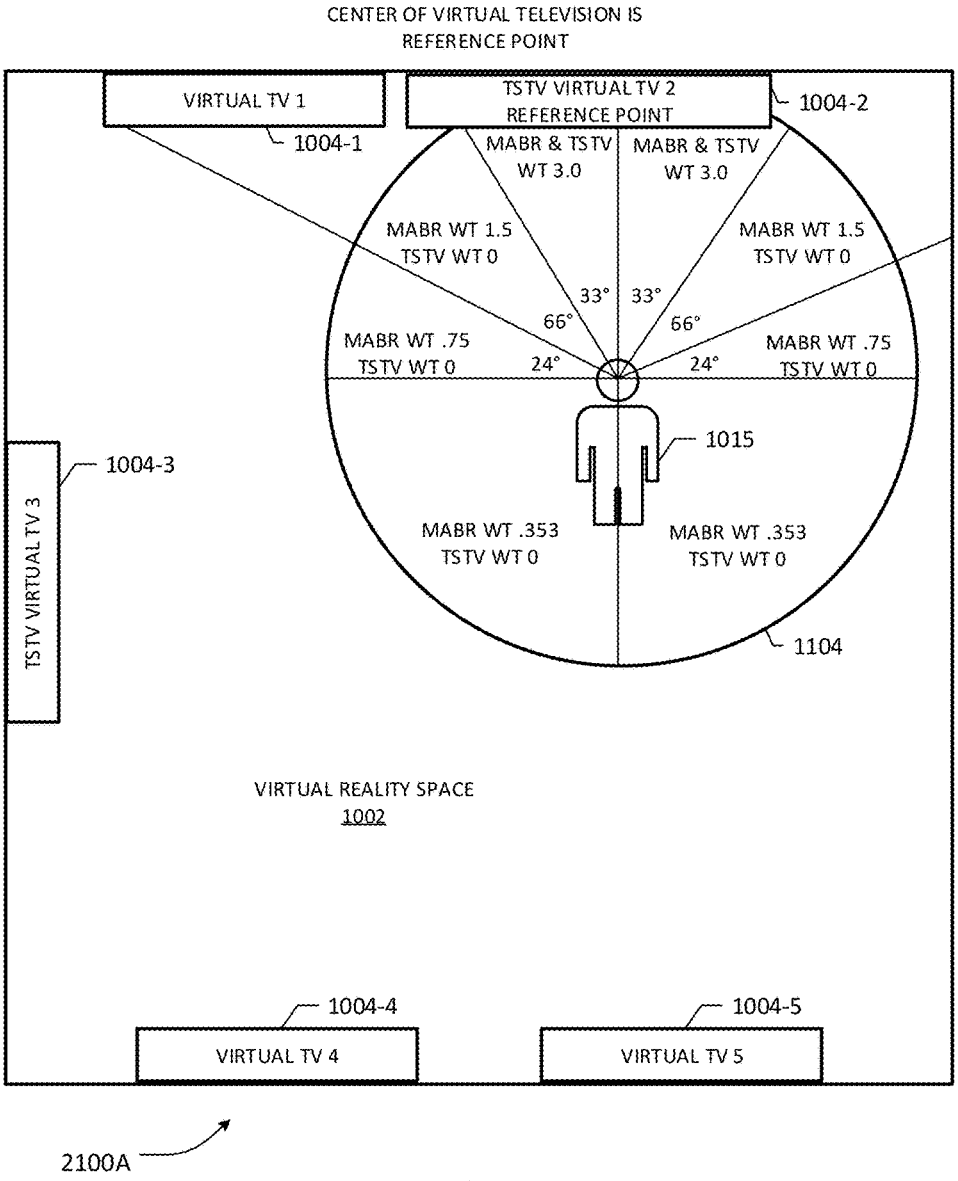


FIG. 21A

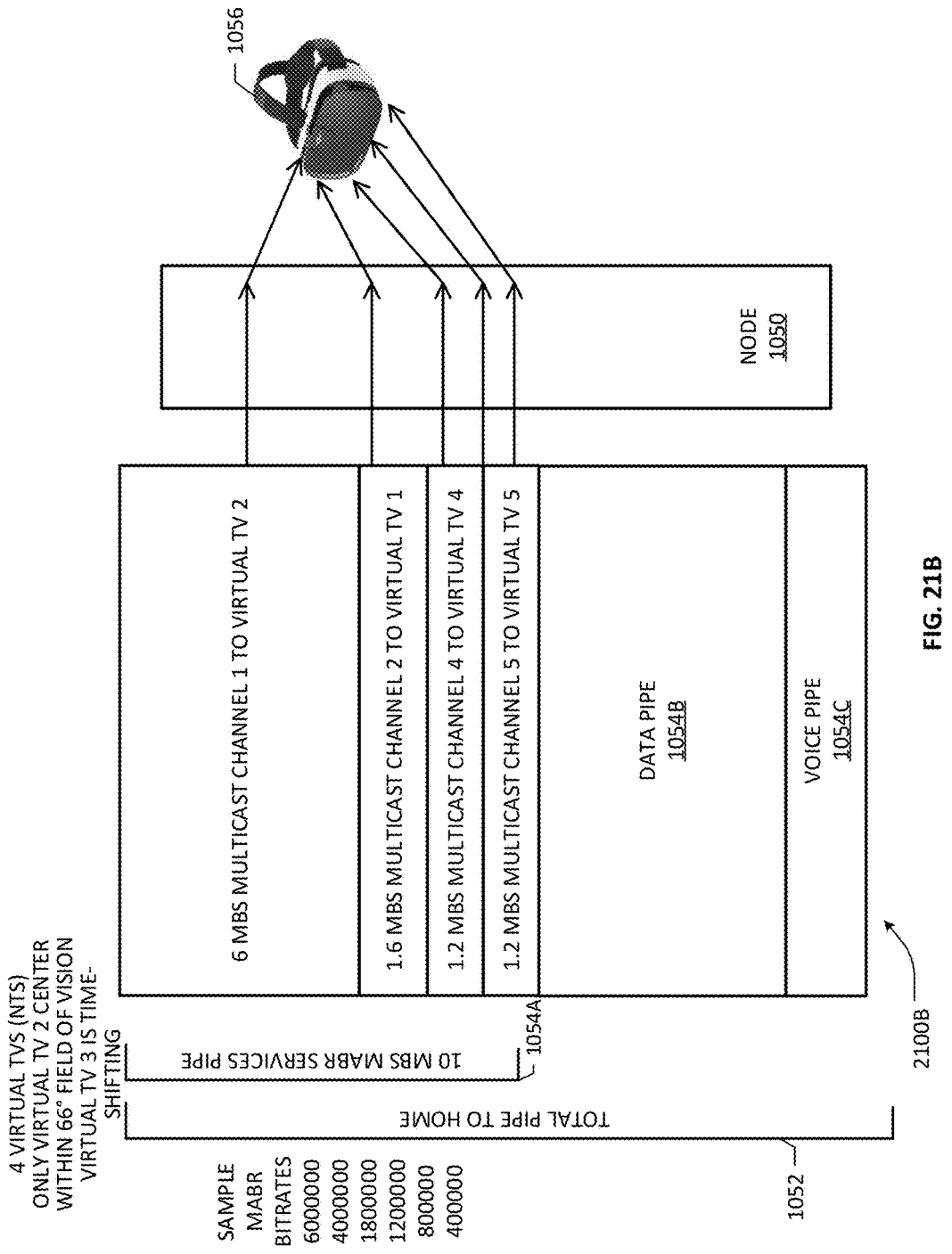

1056
NODE
1050
6 MBS MULTICAST CHANNEL 1 TO VIRTUAL TV 2
1.6 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 1
1.2 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
1.2 MBS MULTICAST CHANNEL 5 TO VIRTUAL TV 5
DATA PIPE
1054B
VOICE PIPE
1054C
2100B
10 MBS MABR SERVICES PIPE
1054A
TOTAL PIPE TO HOME
1052
4 VIRTUAL TVS (NTS)
ONLY VIRTUAL TV 2 CENTER
WITHIN 66° FIELD OF VISION
VIRTUAL TV 3 IS TIME-
SHIFTING
SAMPLE
MABR
BITRATES
6000000
4000000
1800000
1200000
800000
400000

FIG. 21B

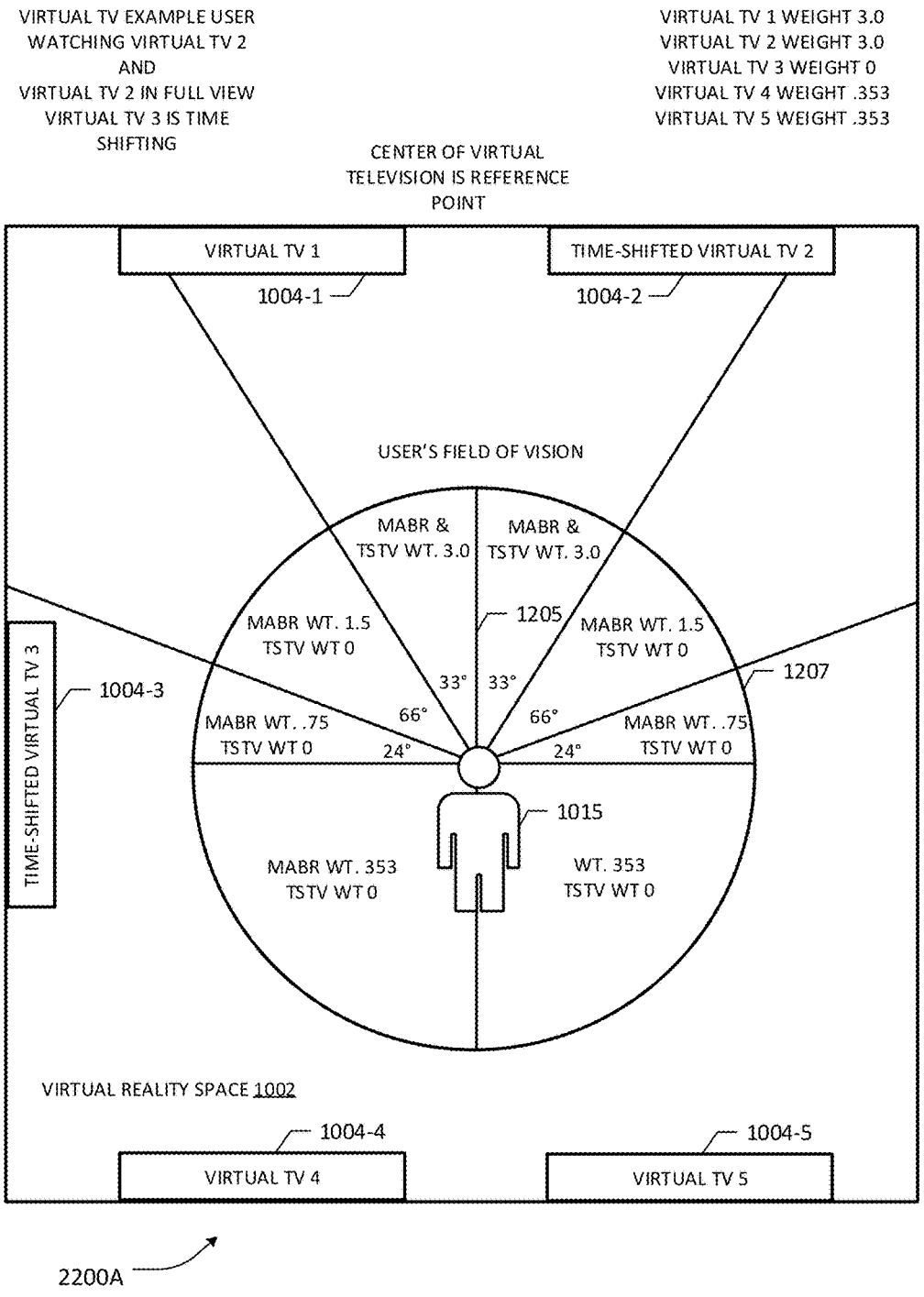

VIRTUAL TV EXAMPLE USER WATCHING VIRTUAL TV 2 AND VIRTUAL TV 2 IN FULL VIEW VIRTUAL TV 3 IS TIME SHIFTING
VIRTUAL TV 1 WEIGHT 3.0
VIRTUAL TV 2 WEIGHT 3.0
VIRTUAL TV 3 WEIGHT 0
VIRTUAL TV 4 WEIGHT .353
VIRTUAL TV 5 WEIGHT .353
CENTER OF VIRTUAL TELEVISION IS REFERENCE POINT
VIRTUAL TV 1
1004-1
TIME-SHIFTED VIRTUAL TV 2
1004-2
USER'S FIELD OF VISION
MABR & TSTV WT. 3.0
MABR & TSTV WT. 3.0
1205
MABR WT. 1.5 TSTV WT 0
MABR WT. 1.5 TSTV WT 0
1207
TIME-SHIFTED VIRTUAL TV 3
1004-3
33°
33°
66°
66°
MABR WT. .75 TSTV WT 0
24°
24°
MABR WT. .75 TSTV WT 0
1015
MABR WT. 353 TSTV WT 0
WT. 353 TSTV WT 0
VIRTUAL REALITY SPACE 1002
1004-4
1004-5
VIRTUAL TV 4
VIRTUAL TV 5
2200A

FIG. 22A

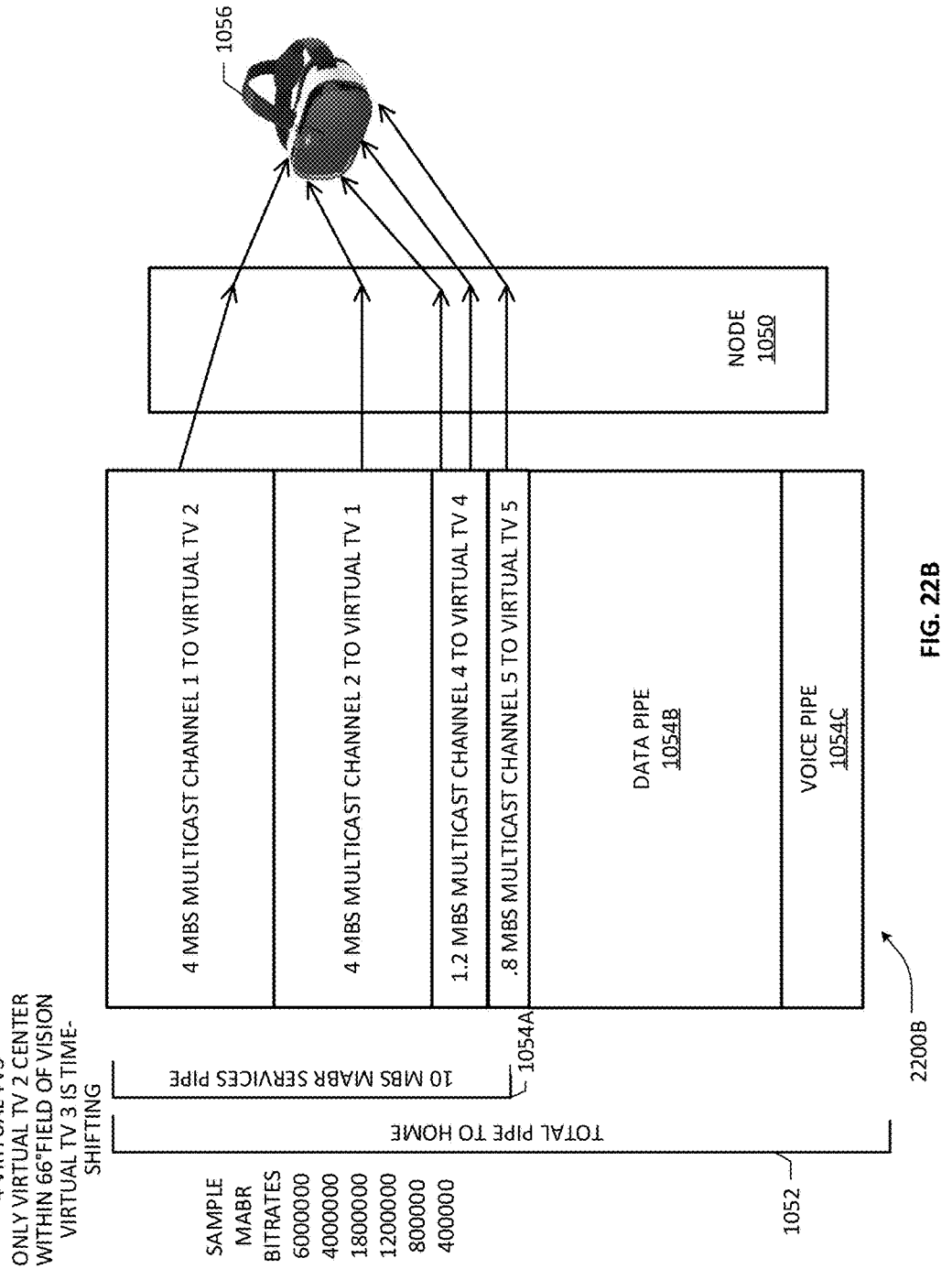

1056
NODE
1050
4 MBS MULTICAST CHANNEL 1 TO VIRTUAL TV 2
4 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 1
1.2 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
.8 MBS MULTICAST CHANNEL 5 TO VIRTUAL TV 5
DATA PIPE
1054B
VOICE PIPE
1054C
2200B
10 MBS MABR SERVICES PIPE
1054A
TOTAL PIPE TO HOME
1052
SAMPLE MABR BITRATES
6000000
4000000
1800000
1200000
800000
400000
4 VIRTUAL TVS
ONLY VIRTUAL TV 2 CENTER
WITHIN 66°FIELD OF VISION
VIRTUAL TV 3 IS TIME-SHIFTING

FIG. 22B

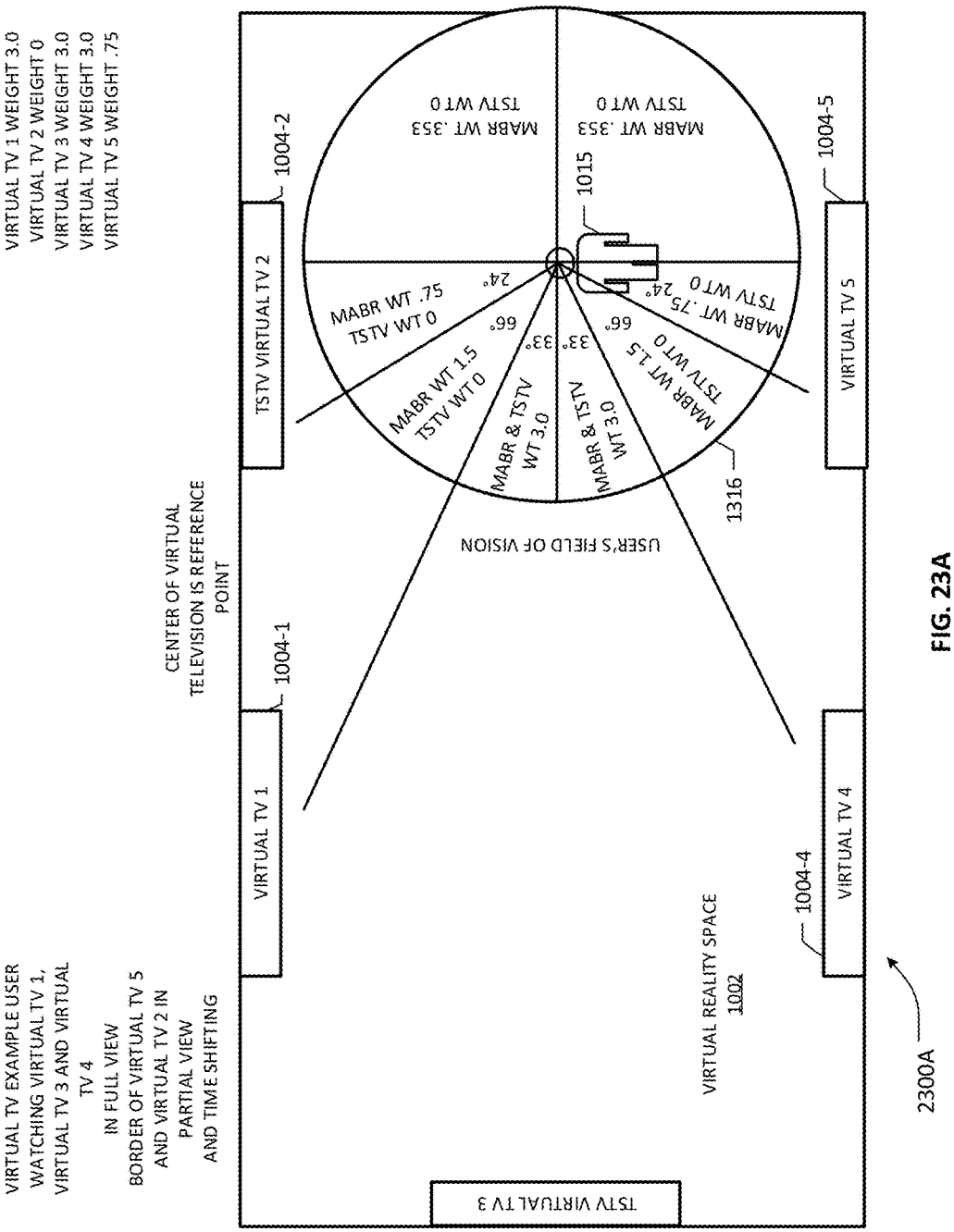

VIRTUAL TV 1 WEIGHT 3.0
VIRTUAL TV 2 WEIGHT 0
VIRTUAL TV 3 WEIGHT 3.0
VIRTUAL TV 4 WEIGHT 3.0
VIRTUAL TV 5 WEIGHT .75
VIRTUAL TV EXAMPLE USER WATCHING VIRTUAL TV 1, VIRTUAL TV 3 AND VIRTUAL TV 4 IN FULL VIEW BORDER OF VIRTUAL TV 5 AND VIRTUAL TV 2 IN PARTIAL VIEW AND TIME SHIFTING
CENTER OF VIRTUAL TELEVISION IS REFERENCE POINT
VIRTUAL REALITY SPACE 1002
USER'S FIELD OF VISION
1004-1
VIRTUAL TV 1
1004-2
TSTV VIRTUAL TV 2
1004-4
VIRTUAL TV 4
1004-5
VIRTUAL TV 5
TSTV VIRTUAL TV 3
1015
1316
2300A
MABR WT .353 TSTV WT 0
MABR WT .353 TSTV WT 0
MABR WT .75 TSTV WT 0
24°
MABR WT 1.5 TSTV WT 0
66°
MABR & TSTV WT 3.0
33°
MABR & TSTV WT 3.0
33°
MABR WT 1.5 TSTV WT 0
66°
MABR WT .75 TSTV WT 0
24°

FIG. 23A

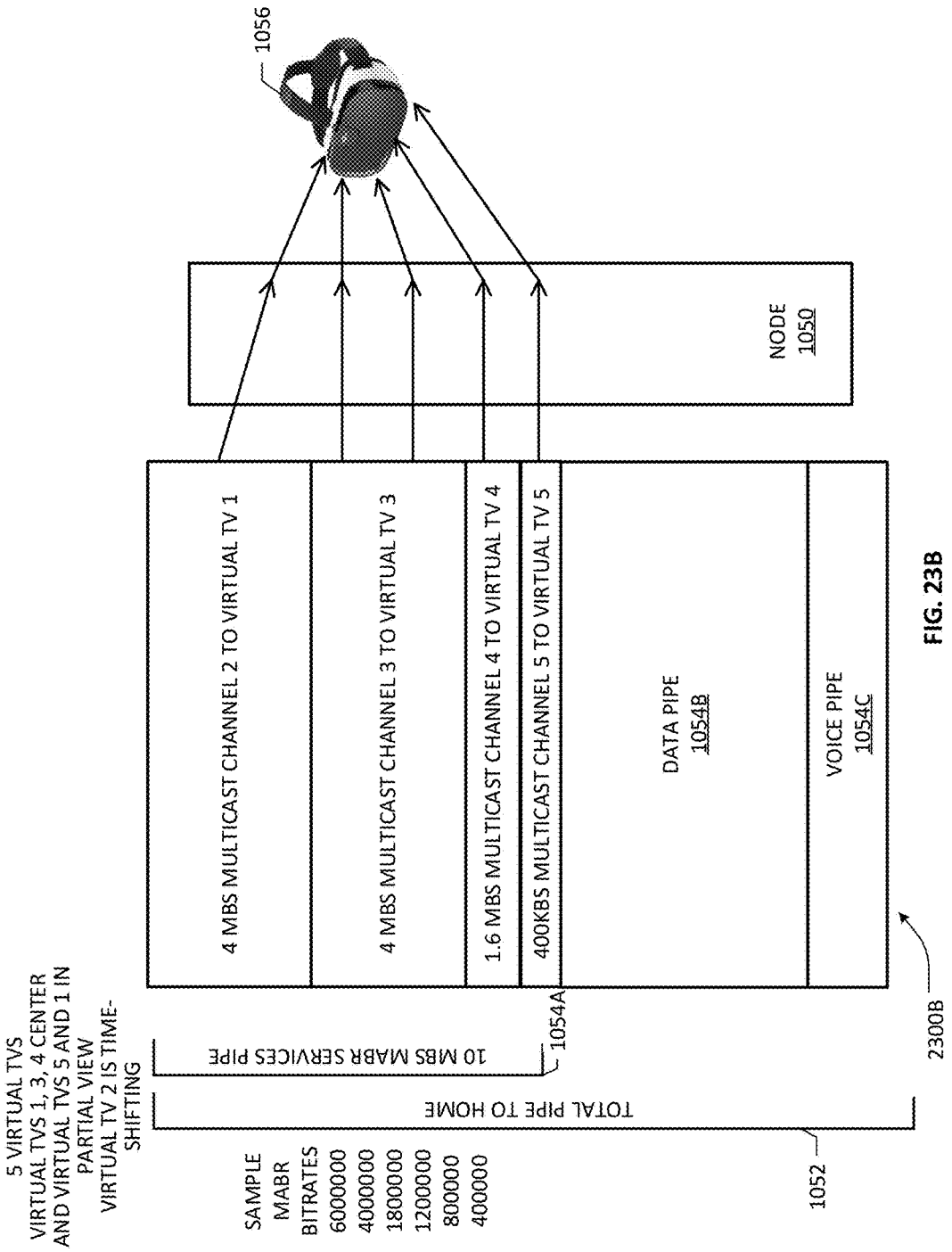

1056
NODE
1050
4 MBS MULTICAST CHANNEL 2 TO VIRTUAL TV 1
4 MBS MULTICAST CHANNEL 3 TO VIRTUAL TV 3
1.6 MBS MULTICAST CHANNEL 4 TO VIRTUAL TV 4
400KBS MULTICAST CHANNEL 5 TO VIRTUAL TV 5
DATA PIPE
1054B
VOICE PIPE
1054C
2300B
10 MBS MABR SERVICES PIPE
1054A
TOTAL PIPE TO HOME
1052
SAMPLE MABR BITRATES
6000000
4000000
1800000
1200000
800000
400000
5 VIRTUAL TVS
VIRTUAL TVS 1, 3, 4 CENTER
AND VIRTUAL TVS 5 AND 1 IN
PARTIAL VIEW
VIRTUAL TV 2 IS TIME-
SHIFTING

FIG. 23B

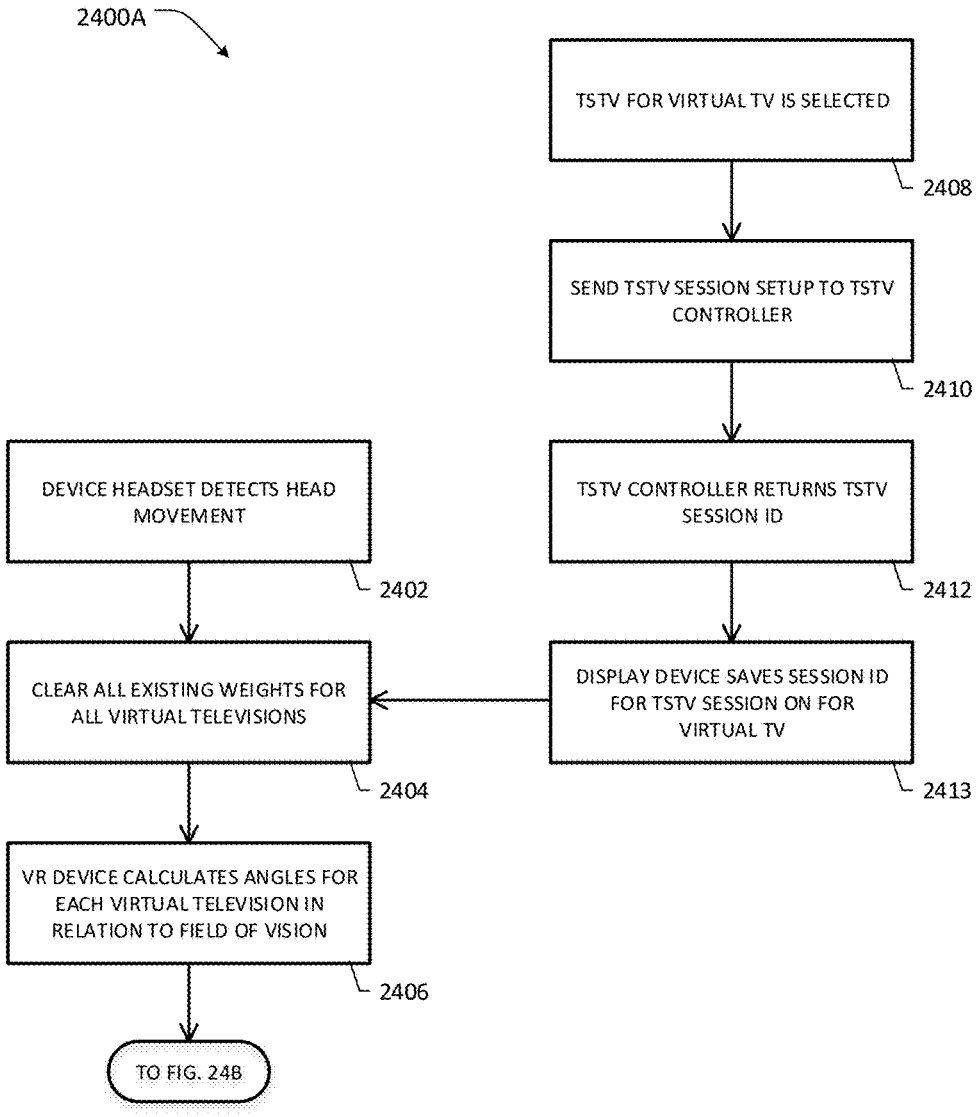

2400A
TSTV FOR VIRTUAL TV IS SELECTED
2408
SEND TSTV SESSION SETUP TO TSTV CONTROLLER
2410
TSTV CONTROLLER RETURNS TSTV SESSION ID
2412
DISPLAY DEVICE SAVES SESSION ID FOR TSTV SESSION ON FOR VIRTUAL TV
2413
DEVICE HEADSET DETECTS HEAD MOVEMENT
2402
CLEAR ALL EXISTING WEIGHTS FOR ALL VIRTUAL TELEVISIONS
2404
VR DEVICE CALCULATES ANGLES FOR EACH VIRTUAL TELEVISION IN RELATION TO FIELD OF VISION
2406
TO FIG. 24B

FIG. 24A

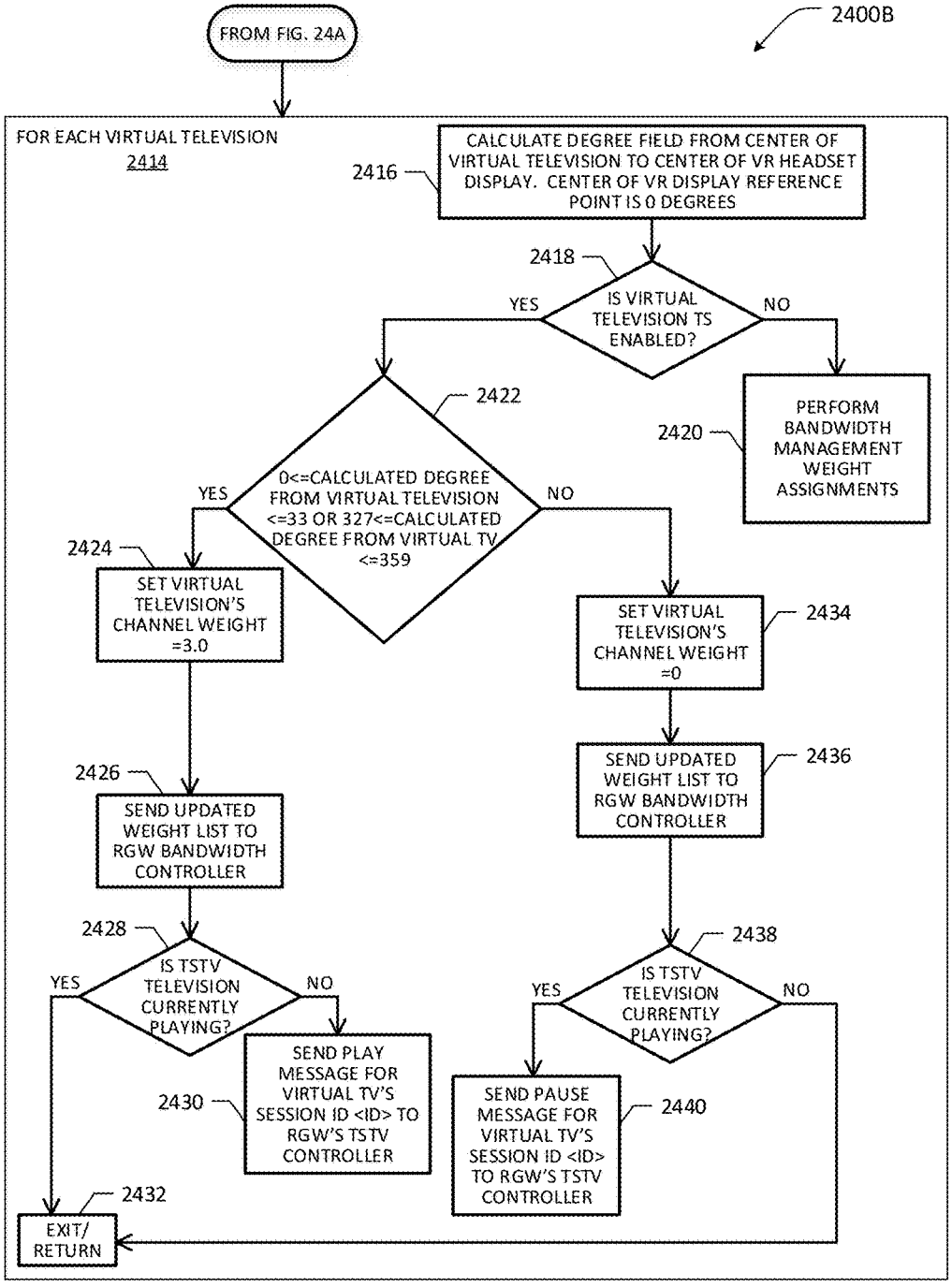

2400B
FROM FIG. 24A
FOR EACH VIRTUAL TELEVISION
2414
2416
CALCULATE DEGREE FIELD FROM CENTER OF VIRTUAL TELEVISION TO CENTER OF VR HEADSET DISPLAY. CENTER OF VR DISPLAY REFERENCE POINT IS 0 DEGREES
2418
IS VIRTUAL TELEVISION TS ENABLED?
YES
NO
2420
PERFORM BANDWIDTH MANAGEMENT WEIGHT ASSIGNMENTS
2422
0<=CALCULATED DEGREE FROM VIRTUAL TELEVISION <=33 OR 327<=CALCULATED DEGREE FROM VIRTUAL TV <=359
YES
NO
2424
SET VIRTUAL TELEVISION'S CHANNEL WEIGHT =3.0
2426
SEND UPDATED WEIGHT LIST TO RGW BANDWIDTH CONTROLLER
2428
IS TSTV TELEVISION CURRENTLY PLAYING?
YES
NO
2430
SEND PLAY MESSAGE FOR VIRTUAL TV'S SESSION ID <ID> TO RGW'S TSTV CONTROLLER
2434
SET VIRTUAL TELEVISION'S CHANNEL WEIGHT =0
2436
SEND UPDATED WEIGHT LIST TO RGW BANDWIDTH CONTROLLER
2438
IS TSTV TELEVISION CURRENTLY PLAYING?
YES
NO
2440
SEND PAUSE MESSAGE FOR VIRTUAL TV'S SESSION ID <ID> TO RGW'S TSTV CONTROLLER
2432
EXIT/ RETURN

FIG. 24B

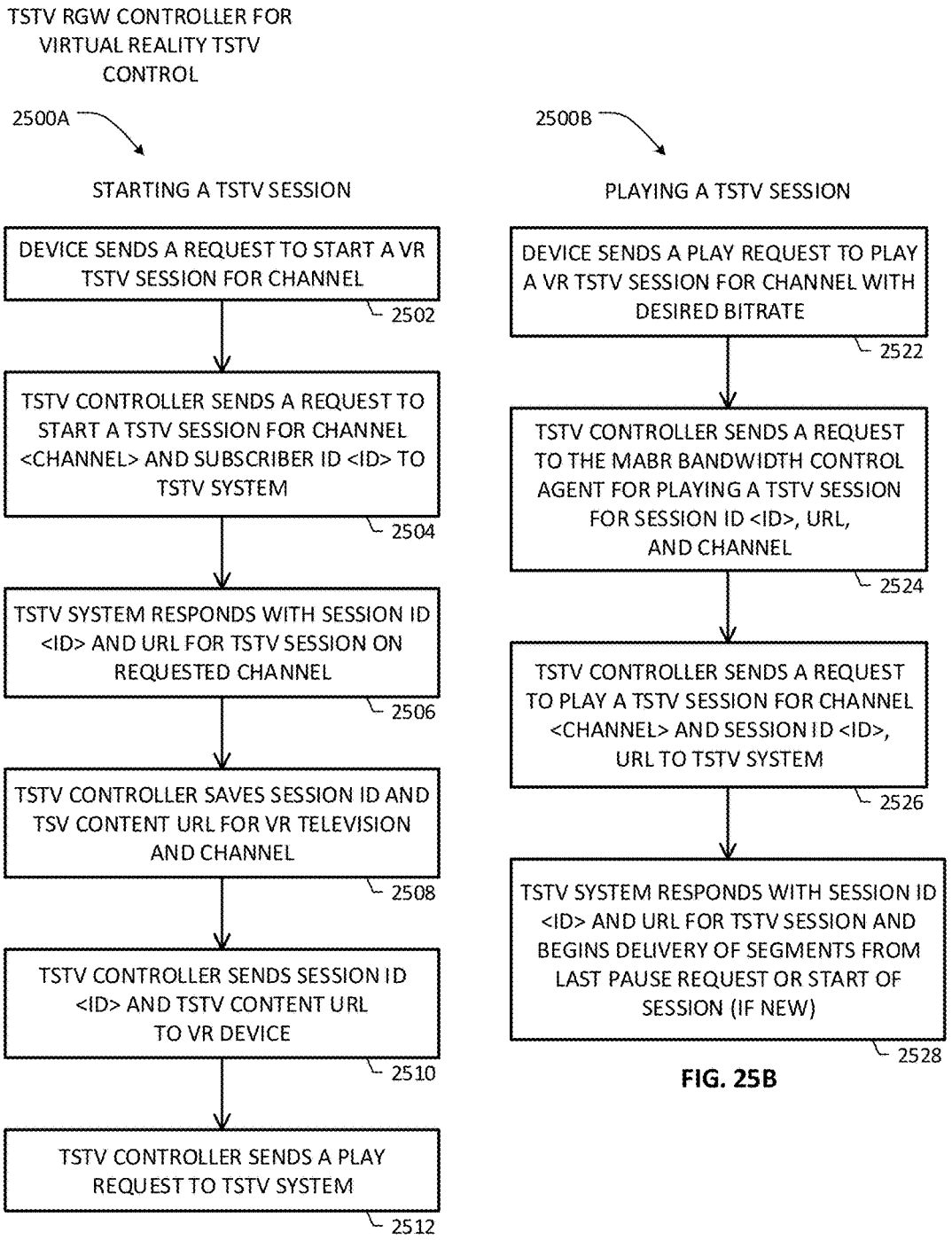


FIG. 25A

FIG. 25B

TSTV RGW CONTROLLER FOR VIRTUAL REALITY TSTV CONTROL

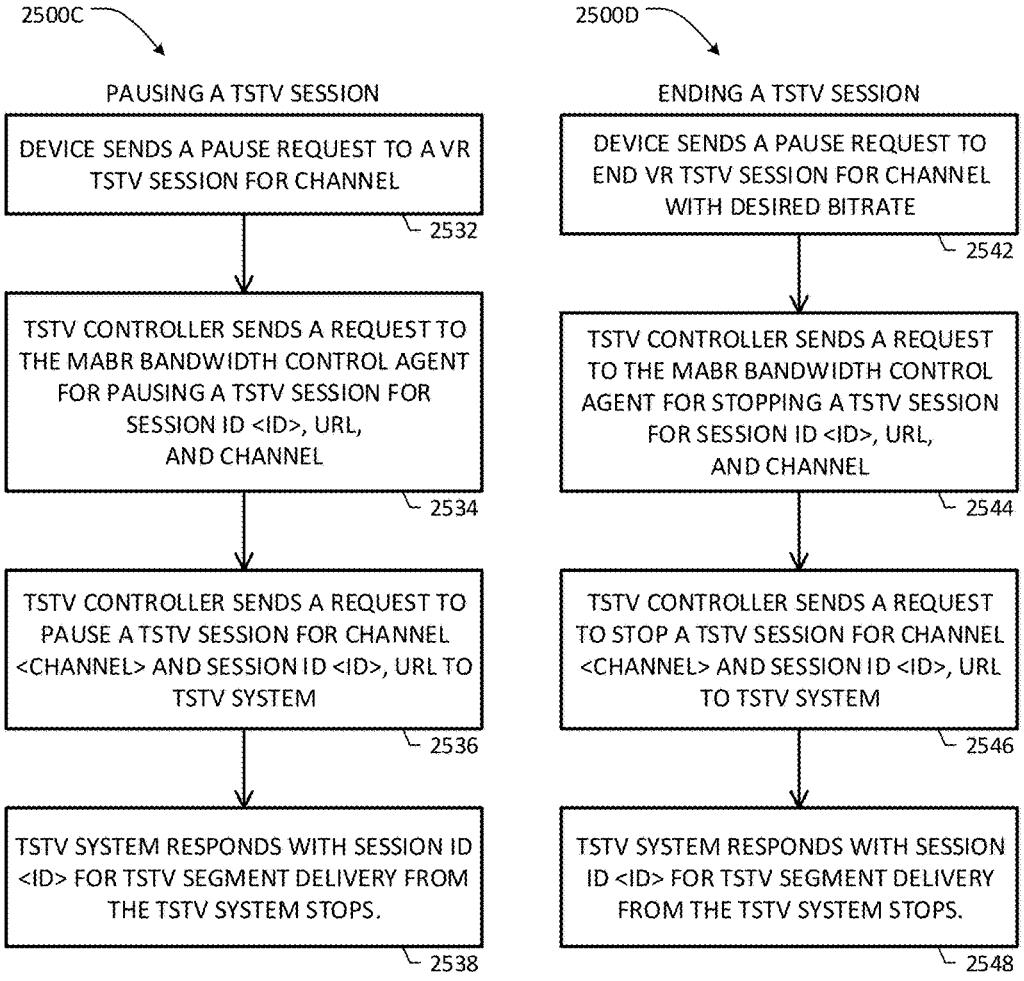


FIG. 25C

FIG. 25D

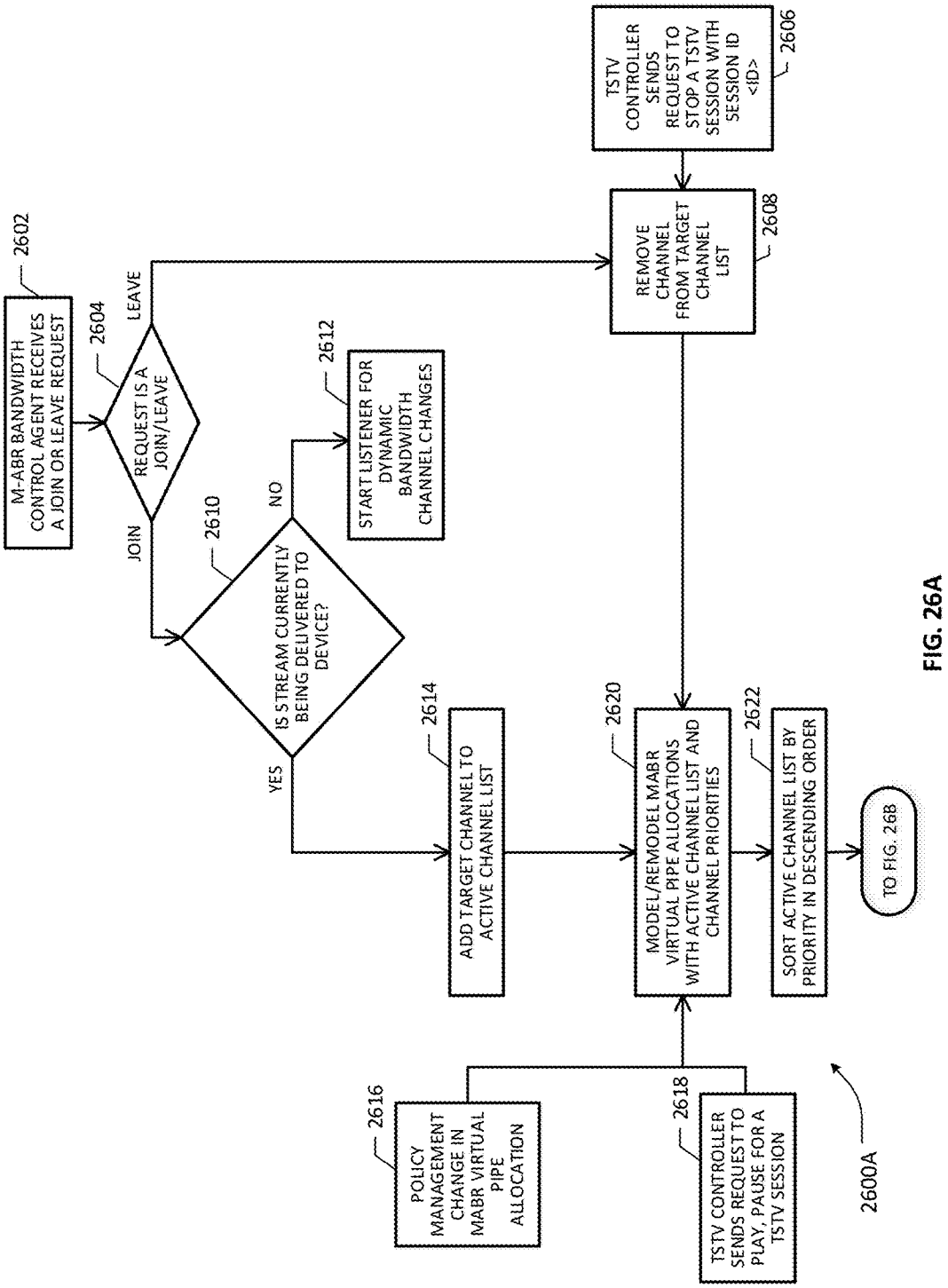

2602
M-ABR BANDWIDTH CONTROL AGENT RECEIVES A JOIN OR LEAVE REQUEST
2604
REQUEST IS A JOIN/LEAVE
JOIN
LEAVE
2610
IS STREAM CURRENTLY BEING DELIVERED TO DEVICE?
NO
YES
2612
START LISTENER FOR DYNAMIC BANDWIDTH CHANNEL CHANGES
2606
TSTV CONTROLLER SENDS REQUEST TO STOP A TSTV SESSION WITH SESSION ID <ID>
2608
REMOVE CHANNEL FROM TARGET CHANNEL LIST
2614
ADD TARGET CHANNEL TO ACTIVE CHANNEL LIST
2620
MODEL/REMODEL MABR VIRTUAL PIPE ALLOCATIONS WITH ACTIVE CHANNEL LIST AND CHANNEL PRIORITIES
2622
SORT ACTIVE CHANNEL LIST BY PRIORITY IN DESCENDING ORDER
TO FIG. 26B
2616
POLICY MANAGEMENT CHANGE IN MABR VIRTUAL PIPE ALLOCATION
2618
TSTV CONTROLLER SENDS REQUEST TO PLAY, PAUSE FOR A TSTV SESSION
2600A

FIG. 26A

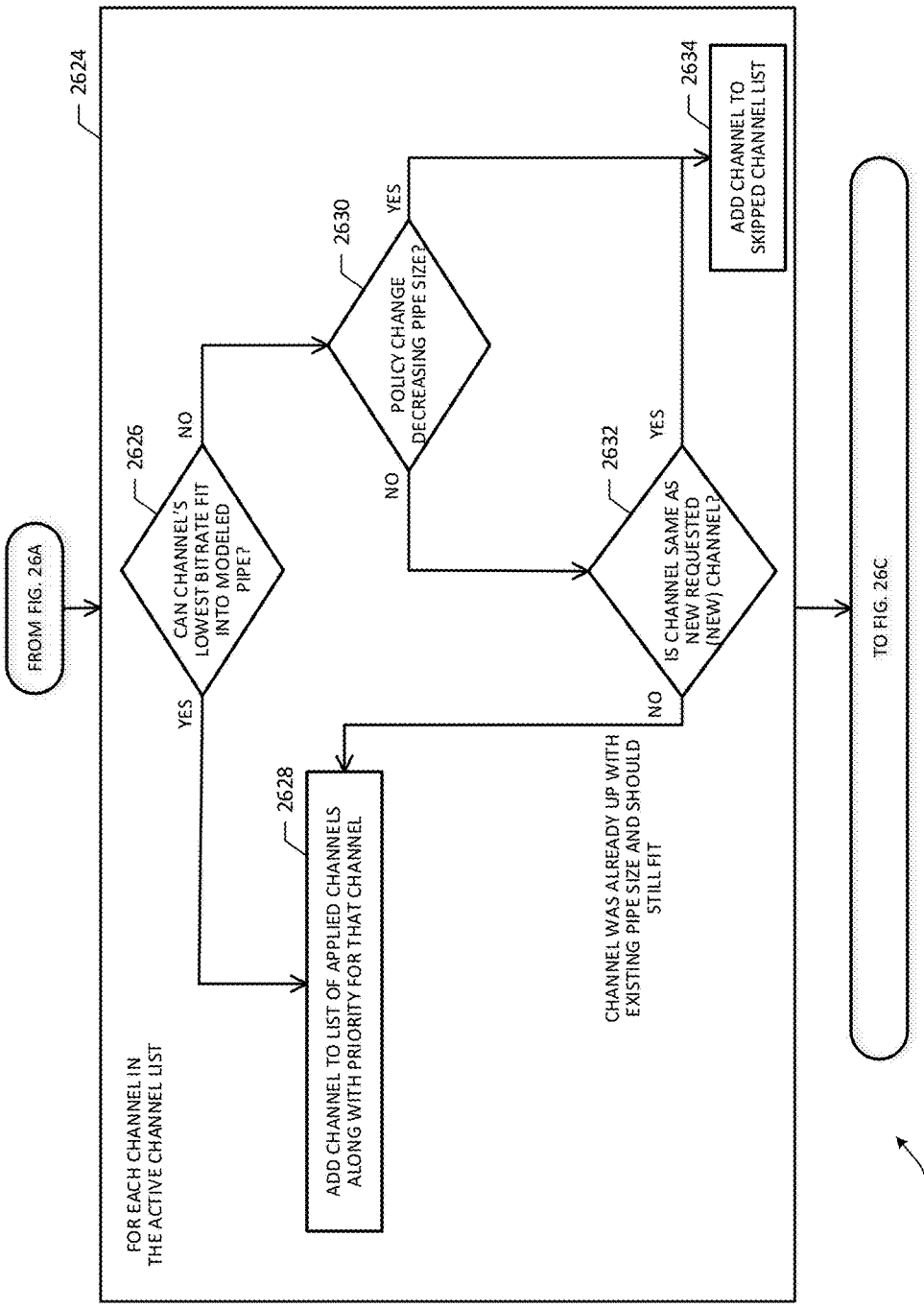

2624
FROM FIG. 26A
2626
CAN CHANNEL'S LOWEST BITRATE FIT INTO MODELED PIPE?
NO
YES
2630
POLICY CHANGE DECREASING PIPE SIZE?
YES
NO
2632
IS CHANNEL SAME AS NEW REQUESTED (NEW) CHANNEL?
YES
NO
2634
ADD CHANNEL TO SKIPPED CHANNEL LIST
2628
ADD CHANNEL TO LIST OF APPLIED CHANNELS ALONG WITH PRIORITY FOR THAT CHANNEL
CHANNEL WAS ALREADY UP WITH EXISTING PIPE SIZE AND SHOULD STILL FIT
FOR EACH CHANNEL IN THE ACTIVE CHANNEL LIST
TO FIG. 26C
2600B

FIG. 26B

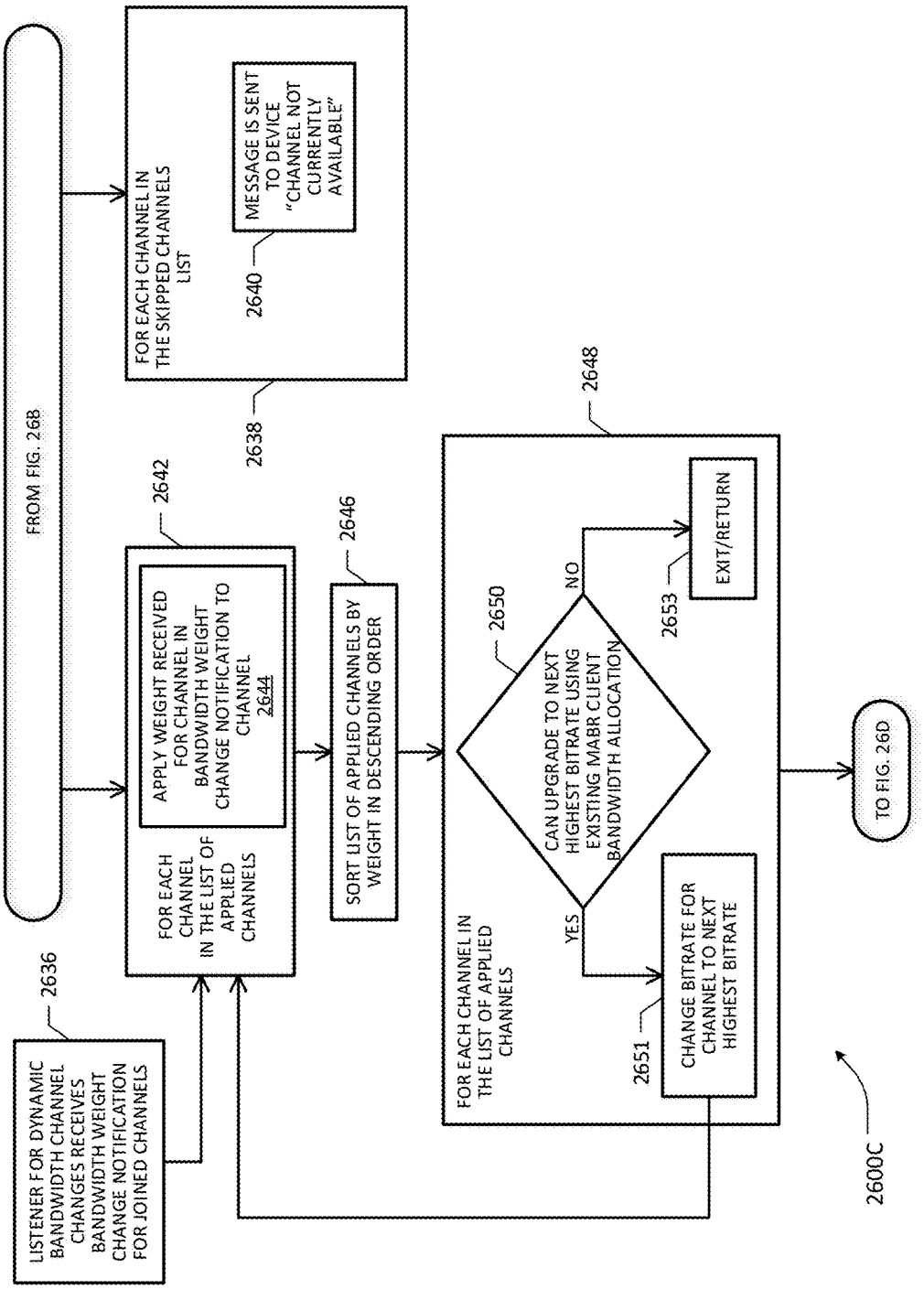

FROM FIG. 26B
2636
LISTENER FOR DYNAMIC BANDWIDTH CHANNEL CHANGES RECEIVES BANDWIDTH WEIGHT CHANGE NOTIFICATION FOR JOINED CHANNELS
FOR EACH CHANNEL IN THE LIST OF APPLIED CHANNELS
2642
APPLY WEIGHT RECEIVED FOR CHANNEL IN BANDWIDTH WEIGHT CHANGE NOTIFICATION TO CHANNEL 2644
2646
SORT LIST OF APPLIED CHANNELS BY WEIGHT IN DESCENDING ORDER
2648
FOR EACH CHANNEL IN THE LIST OF APPLIED CHANNELS
2650
CAN UPGRADE TO NEXT HIGHEST BITRATE USING EXISTING MABR CLIENT BANDWIDTH ALLOCATION
NO
2653
EXIT/RETURN
YES
2651
CHANGE BITRATE FOR CHANNEL TO NEXT HIGHEST BITRATE
TO FIG. 26D
2638
FOR EACH CHANNEL IN THE SKIPPED CHANNELS LIST
2640
MESSAGE IS SENT TO DEVICE "CHANNEL NOT CURRENTLY AVAILABLE"
2600C

FIG. 26C

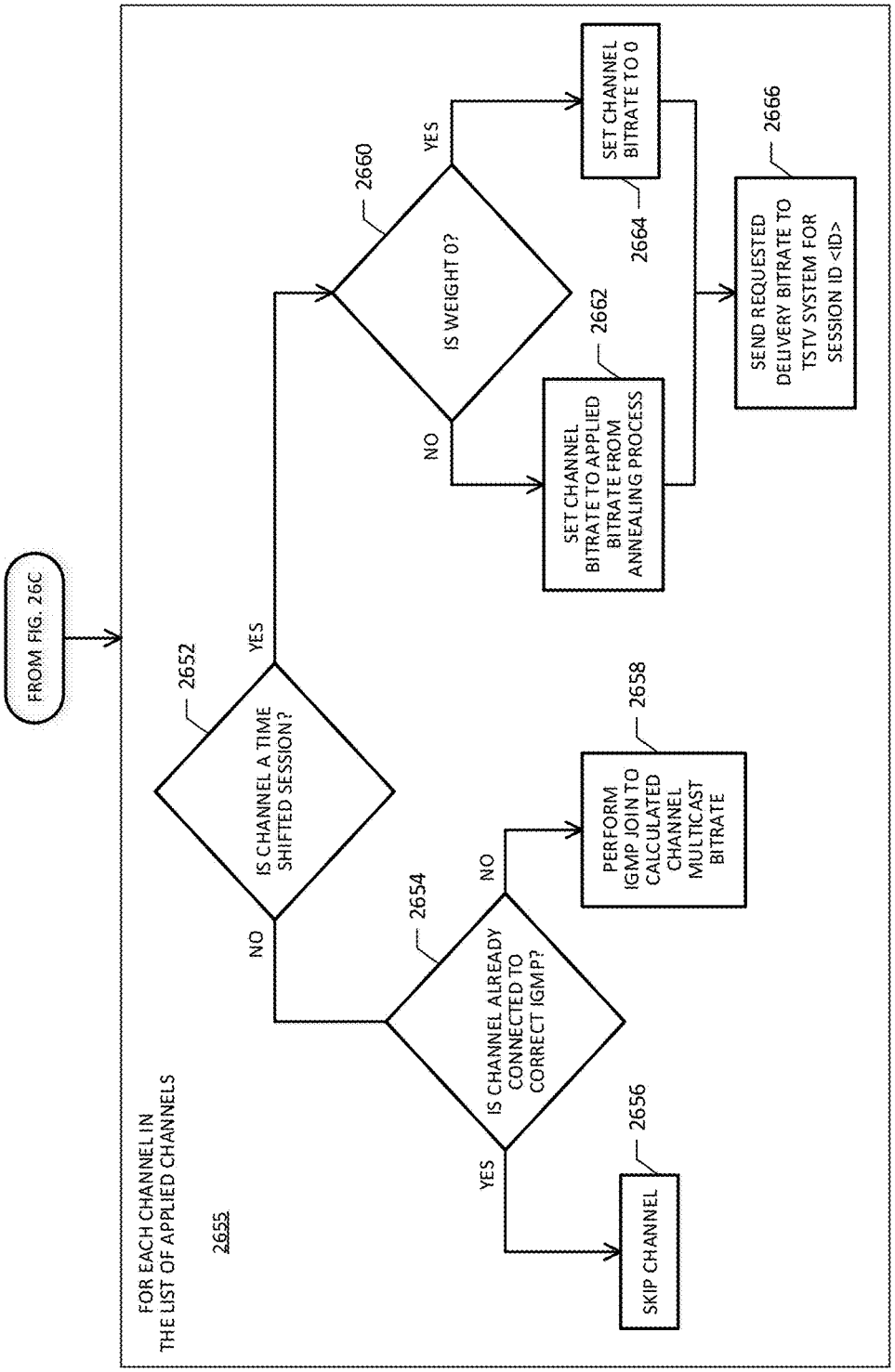

FROM FIG. 26C
FOR EACH CHANNEL IN THE LIST OF APPLIED CHANNELS
2655
IS CHANNEL A TIME SHIFTED SESSION?
2652
YES
NO
IS WEIGHT 0?
2660
YES
NO
SET CHANNEL BITRATE TO 0
2664
SET CHANNEL BITRATE TO APPLIED BITRATE FROM ANNEALING PROCESS
2662
SEND REQUESTED DELIVERY BITRATE TO TSTV SYSTEM FOR SESSION ID <ID>
2666
IS CHANNEL ALREADY CONNECTED TO CORRECT IGMP?
2654
NO
YES
PERFORM IGMP JOIN TO CALCULATED CHANNEL MULTICAST BITRATE
2658
SKIP CHANNEL
2656
2600D

FIG. 26D

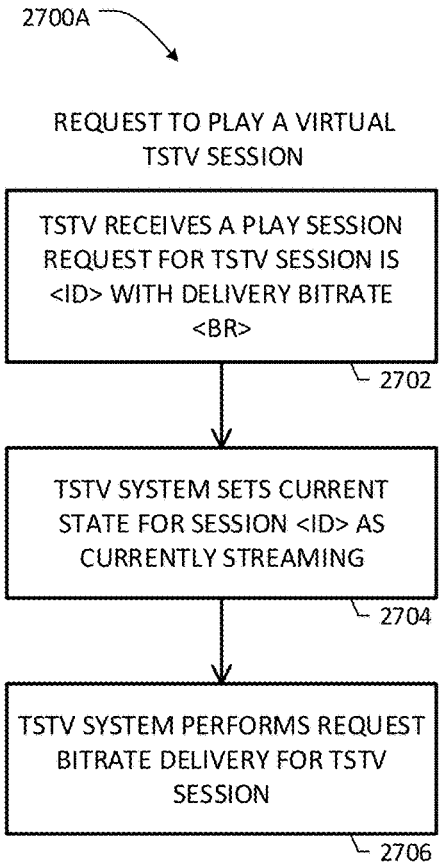


FIG. 27A

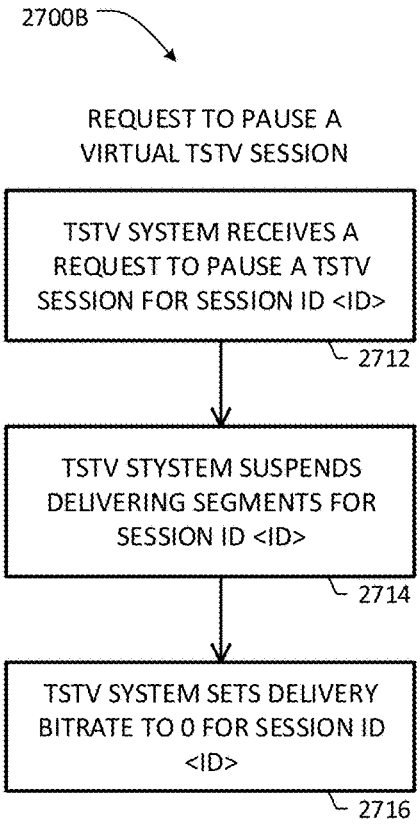


FIG. 27B

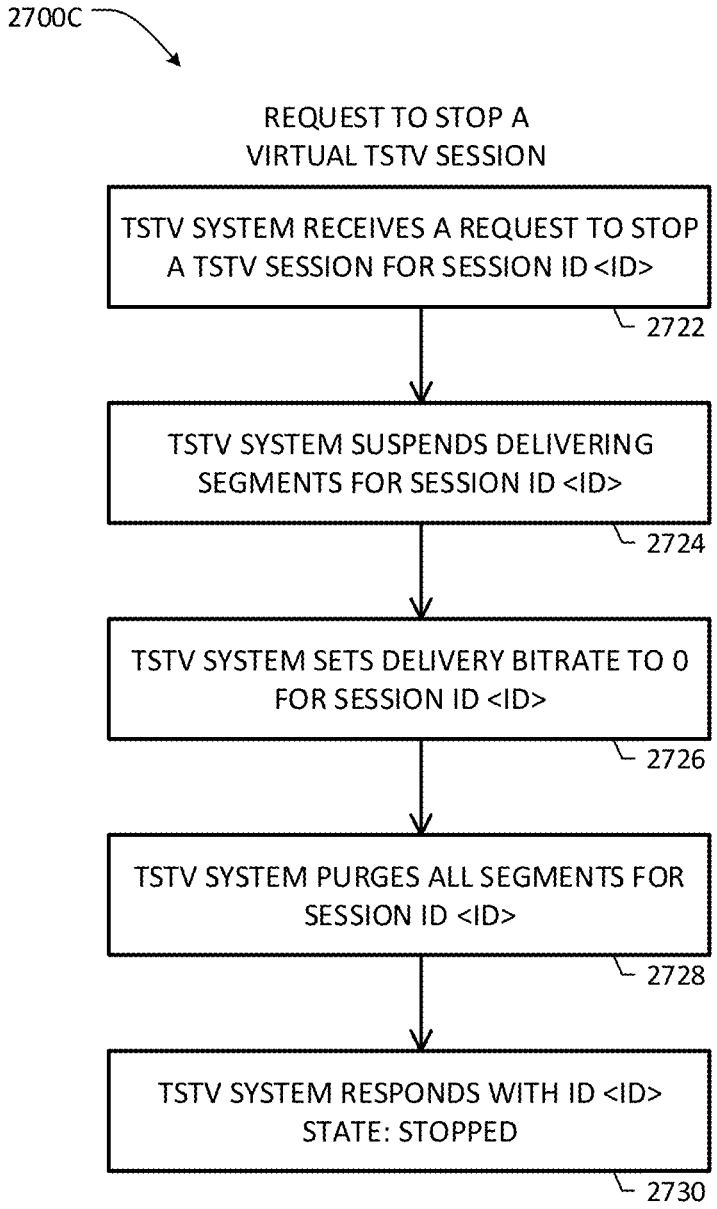

2700C
REQUEST TO STOP A VIRTUAL TSTV SESSION
TSTV SYSTEM RECEIVES A REQUEST TO STOP A TSTV SESSION FOR SESSION ID <ID>
2722
TSTV SYSTEM SUSPENDS DELIVERING SEGMENTS FOR SESSION ID <ID>
2724
TSTV SYSTEM SETS DELIVERY BITRATE TO 0 FOR SESSION ID <ID>
2726
TSTV SYSTEM PURGES ALL SEGMENTS FOR SESSION ID <ID>
2728
TSTV SYSTEM RESPONDS WITH ID <ID> STATE: STOPPED
2730

FIG. 27C

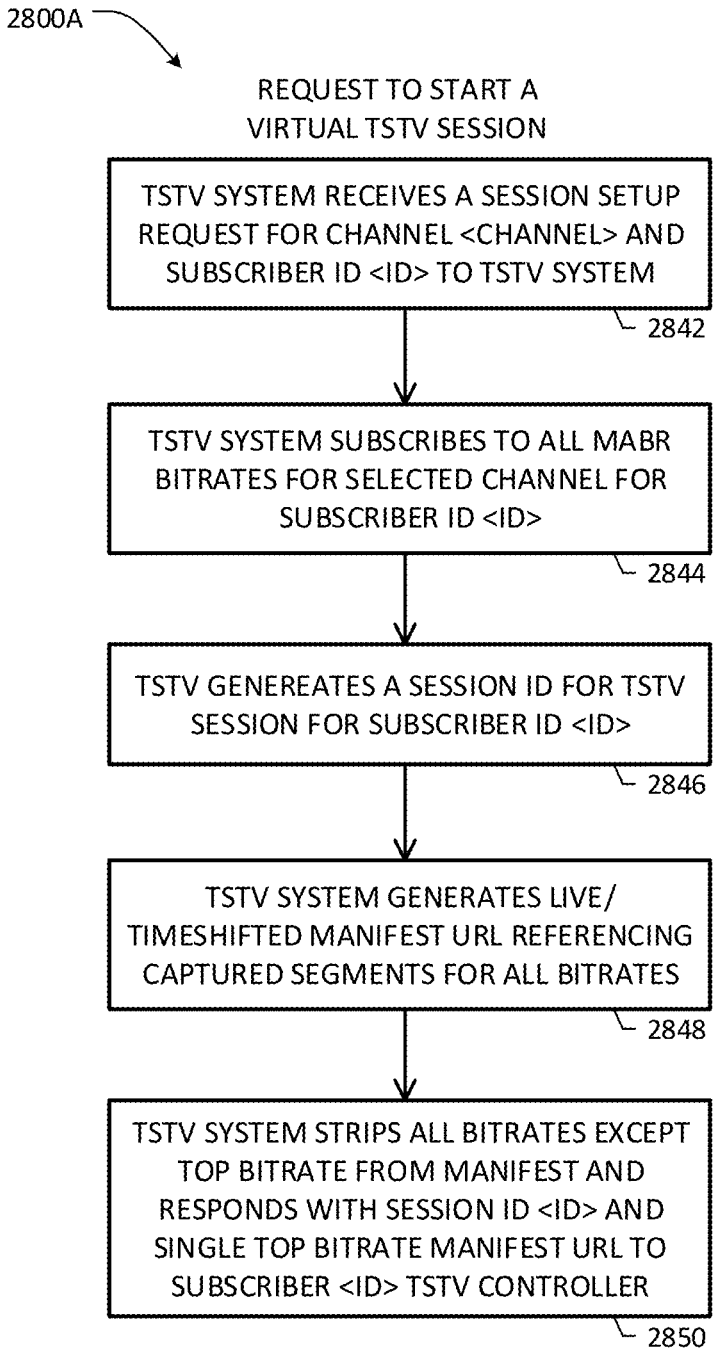

2800A
REQUEST TO START A VIRTUAL TSTV SESSION
TSTV SYSTEM RECEIVES A SESSION SETUP REQUEST FOR CHANNEL <CHANNEL> AND SUBSCRIBER ID <ID> TO TSTV SYSTEM
2842
TSTV SYSTEM SUBSCRIBES TO ALL MABR BITRATES FOR SELECTED CHANNEL FOR SUBSCRIBER ID <ID>
2844
TSTV GENEREATES A SESSION ID FOR TSTV SESSION FOR SUBSCRIBER ID <ID>
2846
TSTV SYSTEM GENERATES LIVE/ TIMESHIFTED MANIFEST URL REFERENCING CAPTURED SEGMENTS FOR ALL BITRATES
2848
TSTV SYSTEM STRIPS ALL BITRATES EXCEPT TOP BITRATE FROM MANIFEST AND RESPONDS WITH SESSION ID <ID> AND SINGLE TOP BITRATE MANIFEST URL TO SUBSCRIBER <ID> TSTV CONTROLLER
2850

FIG. 28A

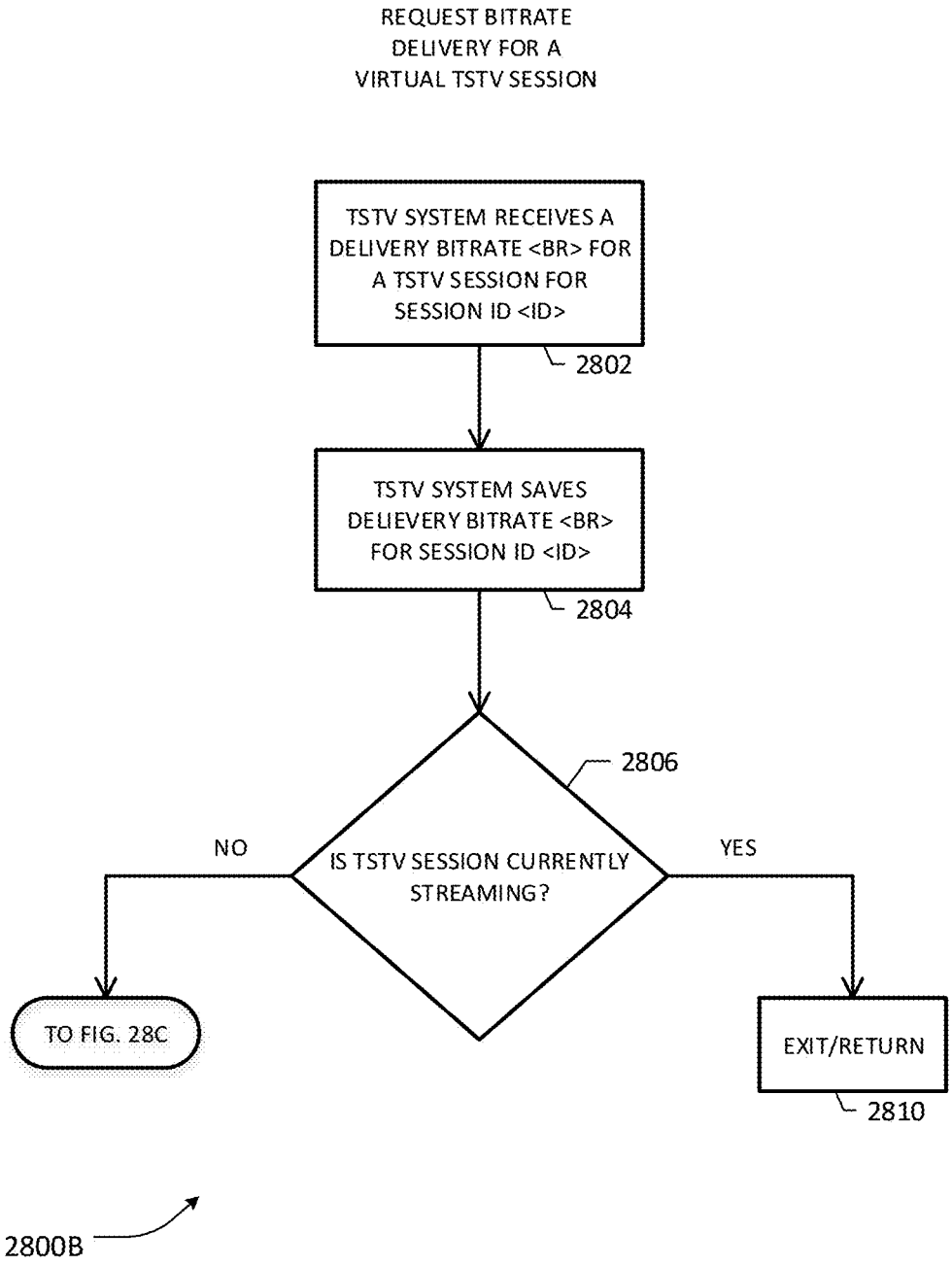

REQUEST BITRATE DELIVERY FOR A VIRTUAL TSTV SESSION
TSTV SYSTEM RECEIVES A DELIVERY BITRATE
 FOR A TSTV SESSION FOR SESSION ID <ID>
2802
TSTV SYSTEM SAVES DELIEVERY BITRATE
 FOR SESSION ID <ID>
2804
2806
IS TSTV SESSION CURRENTLY STREAMING?
NO
YES
TO FIG. 28C
EXIT/RETURN
2810
2800B

FIG 28B

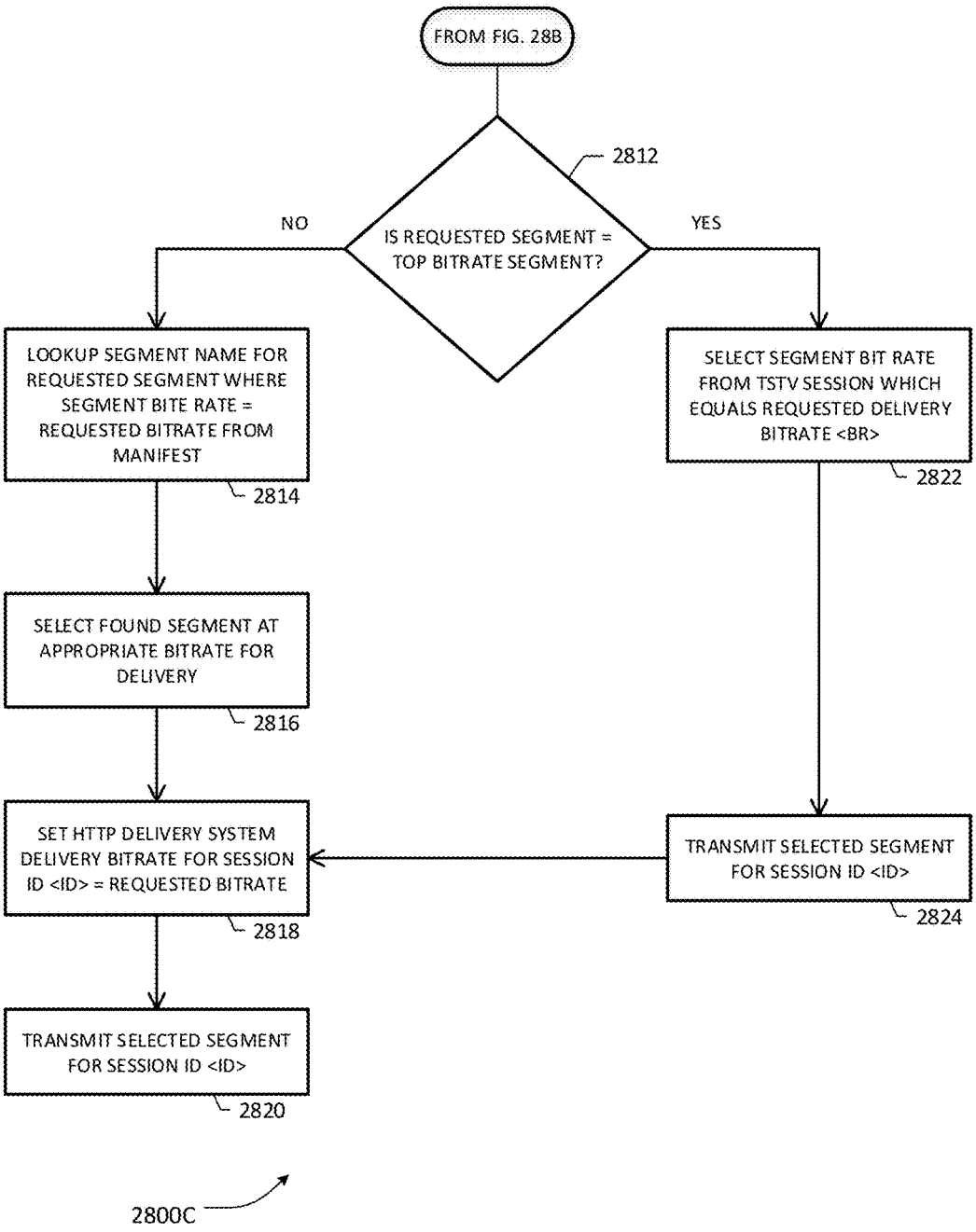

FROM FIG. 28B
2812
IS REQUESTED SEGMENT = TOP BITRATE SEGMENT?
NO
YES
LOOKUP SEGMENT NAME FOR REQUESTED SEGMENT WHERE SEGMENT BITE RATE = REQUESTED BITRATE FROM MANIFEST
2814
SELECT FOUND SEGMENT AT APPROPRIATE BITRATE FOR DELIVERY
2816
SET HTTP DELIVERY SYSTEM DELIVERY BITRATE FOR SESSION ID <ID> = REQUESTED BITRATE
2818
TRANSMIT SELECTED SEGMENT FOR SESSION ID <ID>
2820
SELECT SEGMENT BIT RATE FROM TSTV SESSION WHICH EQUALS REQUESTED DELIVERY BITRATE
2822
TRANSMIT SELECTED SEGMENT FOR SESSION ID <ID>
2824
2800C

FIG. 28C

BITRATE CONTROL IN A VIRTUAL REALITY (VR) ENVIRONMENT

PRIORITY UNDER 35 U.S.C. § 119(e) & 37 C.F.R. § 1.78

This nonprovisional application claims priority based upon the following prior United States provisional patent application(s): (i) "BITRATE CONTROL IN VIRTUAL REALITY (VR) ENVIRONMENT," Application No. 62/384,934, filed Sep. 8, 2016, in the name(s) of Christopher Phillips, Robert Forsman, Jennifer Reynolds and Charles Dasher; each of which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The present disclosure generally relates to communication networks. More particularly, and not by way of any limitation, the present disclosure is directed to a scheme for facilitating bitrate control in a virtual reality (VR) environment operative to receive multiple content streams in a multicast adaptive bitrate (MABR) architecture.

BACKGROUND

The near universal adoption of Internet protocol (IP) as a standard for digital transmission is revolutionizing the traditional way of video delivery. Typical applications such as IPTV and live video streaming have become increasingly popular over the Internet. To efficiently utilize the bandwidth resources of the network in these applications, the video is usually compressed with suitable media coding schemes and then delivered only to subscribers who request it. For data delivery, multicast is considered the most efficient paradigm for such applications, but the scalability issue of traditional IP multicast hinders the deployment of a large-scale video delivery system with numerous channels.

IP delivery is also contemplated in virtual reality environments or applications that allow for virtual media viewing areas, including ones with multiple virtual TVs or screens. Mixed reality environments allow for virtual televisions to be displayed instead of (or alongside with) real televisions in a real environment. Virtual reality requires extremely high bitrates because the true "screen" is much closer to a viewer's eye than for an actual television ten feet away. Lower bitrates in a virtual environment cause a "screen door" effect, in which individual pixels are visible even if they would not be ten feet away.

It should be appreciated that a major challenge for existing virtual reality systems is combining realistic images with low-latency rendering, so that user's virtual reality experience matches the rapid feedback to movement observed in real environments. Existing systems often have long latency to measure changes in the user's position and orientation, and to rerender the virtual world based on these changes. 3D rendering is a complex and processor intensive operation that can take potentially hundreds of milliseconds. The result is that users perceive noticeable lag between their movements and the rendering of updated virtual environments on their displays. Three technology trends are compounding this challenge: (a) The complexity of 3D models is growing as more 3D data is captured and generated; (b) Resolution of virtual reality displays is increasing, requiring more computational power to render images; and (c) Users are relying increasingly on mobile devices that may have limited resources or capacity. As a result of these trends, high

latency in rendering virtual reality displays has become a major factor limiting adoption and applications of virtual reality technology. There are no known systems that provide sufficiently low-latency rendering and display to generate highly responsive virtual reality environments given these technology constraints, including where media delivery is contemplated.

SUMMARY

The present patent disclosure is broadly directed to systems, methods, apparatuses, devices, and associated non-transitory computer-readable media for providing bitrate control in delivering media content to a plurality of virtual display (VD) screens presented in a virtual reality (VR) environment effectuated by a VR device of a subscriber based on detecting a movement in a point of view with respect the VD screens' placement within the VR environment, wherein each VD screen is configured to receive a media content channel.

Some embodiments herein provide a virtual reality environment that includes detecting where a viewer is facing, and calculating weights to give virtual televisions or screens based on how "in view" they are. These weights may determine audio volume and video bitrate. Overall quality of experience is maintained, since quality is less crucial for VD screens in periphery vision. At the same time, users are able to notice when important events occur on non-primary VD screens of televisions from audio and/or visual cues. Upon shifting focus, televisions that were previously in peripheral vision increase in quality and volume.

Because VD screens in an example virtual environment are always playing, they respond fluidly to rapid user head motions. A user can quickly glance at a television to see if anything is interesting. Should they be interested, quality will improve within a short time as the video decoder's buffer is filled with higher quality segments. At the same time, bandwidth is conserved for televisions that are not currently being watched, allowing greater bandwidth to be allocated for televisions that are.

Some embodiments herein provide a virtual reality environment system that detects where a viewer is facing, and only plays video that is seen. Un-played video may be time-shifted, allowing unwatched segments to be viewed at a later time. Improved QoE may therefore be maintained, since the only data that is used is wanted data. At the same time, content is not missed. Upon shifting focus, televisions that were previously paused resume playback exactly where they were last viewed. Non time-shifted televisions can have their bandwidth managed as set forth in the embodiments described elsewhere in the present patent application.

In one aspect, an embodiment of a bitrate control method is disclosed for delivering media content to a plurality of VD screens presented in a VR environment effectuated by a VR device of a subscriber, wherein each VD screen is configured to receive a media content channel. The claimed embodiment comprises, inter alia, detecting a movement in a point of view of the subscriber in relation to a reference axis (e.g., a first reference axis) with respect the VD screens' placement within the VR environment. In one variation, the point of view movement may result in a second reference axis within the VR environment. An angular distance may be computed or otherwise determined with respect to each of the VD screens based on the point of view movement. For example, such an angular distance or displacement may be determined for the VD screens relative to a new or second reference axis. Weights for each of the media content

channels may be assigned or updated based on the angular distance of the corresponding VD screens relative to point of view movement. Based on the assigned and/or updated weights of the media content channels, bandwidth of a managed bandwidth pipe configured for delivering the media content channels to the subscriber's VR environment may be allocated or reallocated.

In another aspect, an embodiment of a bitrate control method may involve time-shifting of the media in a VR environment having a plurality of VD screens. Similar to the embodiment set forth above, an angular distance may be computed or otherwise determined with respect to each of the VD screens based on the point of view movement of a subscriber. A determination may be made that as to whether one or more VD screens are outside a field of view of the subscriber. For each of the media content channels showing on the VD screens still within the subscriber's field of view, suitable weights may be assigned and/or updated based on the angular distance of the corresponding VD screens. On the other hand, a null weight may be assigned to the media content channels showing on the VD screens that are outside the subscriber's field of view. The media content channels showing on the VD screens determined to be outside the subscriber's field of view are time-shifted. Bandwidth of the subscriber's managed bandwidth pipe may be allocated or reallocated based on the assigned/updated weights of the media content channels upon taking into account the null weights of the time-shifted media content channels for delivering the media content channels to the VD screens determined to be within the subscriber's field of view.

In a multiscreen virtual television environment, embodiments herein therefore advantageously provide a bitrate selection and bandwidth distribution scheme based on how directly a user is viewing a television.

In some embodiments, responsive to detecting the user's head or ocular movement, angular distance of each of the VD screens relative to a reference axis is computed. Weights to each of the media content channels may be assigned or updated based on the angular distance of the corresponding VD screens relative to the reference axis. According to a channel bandwidth annealing mechanism, bandwidth of a managed bandwidth pipe may be (re)allocated based on the relative weights of the media content channels for delivering the media content channels to the subscriber's VR environment responsive to selecting single bitrates for the media channels.

In still further aspects, one or more embodiments of a non-transitory computer-readable medium or distributed media containing computer-executable program instructions or code portions stored thereon are disclosed for performing one or more embodiments of the methods of the present invention when executed by a processor entity of a network node, element, virtual appliance, UE device, and the like, mutatis mutandis. Further features of the various embodiments are as claimed in the dependent claims.

With respect to embodiments providing for time-shifting, bandwidth may be further conserved for VD screens that are not currently being watched, thereby allowing greater bandwidth to be allocated for the screens being watched. Additional benefits and advantages of the embodiments will be apparent in view of the following description and accompanying Figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present disclosure are illustrated by way of example, and not by way of limitation, in the Figures of the accompanying drawings in which like references indicate similar elements. It should be noted that different references to "an" or "one" embodiment in this disclosure are not necessarily to the same embodiment, and such references may mean at least one. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

The accompanying drawings are incorporated into and form a part of the specification to illustrate one or more exemplary embodiments of the present disclosure. Various advantages and features of the disclosure will be understood from the following Detailed Description taken in connection with the appended claims and with reference to the attached drawing Figures in which:

FIG. **1** depicts an example multicast ABR (MABR) network architecture for facilitating delivery of media content to one or more virtual display (VD) screens of a virtual reality (VR) environment of a subscriber premises according to one or more embodiments of the present patent application;

FIG. **2** depicts a network portion or subsystem that may be arranged as at least part of an apparatus for facilitating delivery of media content as multi-bitrate representations of gapped MABR segment streams in an MABR network architecture of FIG. **1** according to one embodiment;

FIGS. **3**A-**3**C depict further details of a network portion of an example MABR network architecture of FIG. **1** for providing gapped MABR segment streams as media content channels to a plurality of subscriber premises according to an embodiment for purposes of the present patent application;

FIGS. **4**A and **4**B depict block diagrams of a subscriber premises gateway or node and a subscriber premises configured according to an embodiment of the present invention for delivering select single bitrate representations of the media content channels to VD screens of a subscriber's VR environment in an example architecture;

FIG. **5** is an example VR environment effectuated by a VR apparatus device of a subscriber for presenting a plurality of VD screens according to an embodiment for purposes of the present patent disclosure;

FIGS. **6**A and **6**B are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements, with or without additional flowcharts of the present disclosure, for facilitating a bitrate control scheme in respect of delivering media content channels to VD screens according to an embodiment;

FIG. **7** is a flowchart of various blocks, steps and/or acts that may be (re)combined in one or more embodiments for facilitating a bitrate control scheme in additional detail;

FIGS. **8**A and **8**B depict portions of a flowchart comprising various blocks, steps and/or acts that may be (re) combined in one or more arrangements that illustrate an example weight (re)assignment and/or updating process according to one embodiment of the present patent disclosure;

FIGS. **9**A-**9**D depict portions of a flowchart comprising various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate an example channel annealing mechanism for dynamic selection of media content channel bitrates according to one embodiment of the present patent disclosure;

FIGS. **10**A and **10**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in an illustrative use case scenario;

FIGS. **11**A and **11**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in another illustrative use case scenario;

FIGS. **12**A and **12**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in yet another illustrative use case scenario;

FIGS. **13**A and **13**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in yet another illustrative use case scenario;

FIG. **14** depicts a block diagram of an apparatus for segmenting media/content channels for purposes of an embodiment of the present patent application;

FIG. **15** depicts a block diagram of a computer-implemented apparatus that may be configured as a gateway node or subsystem operative in an MABR communications network of the present invention;

FIGS. **16**A and **16**B depict block diagrams of a subscriber premises gateway or node and a subscriber premises configured according to an embodiment of the present invention for delivering select single bitrate representations of the media content channels to VD screens in addition to facilitating time-shifting of selected media content channels of a subscriber's VR environment in an example architecture;

FIGS. **17**A and **17**B are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements, with respect to the embodiments of FIGS. **6**A and/or **6**B, in a further embodiment of the present invention;

FIGS. **18**A and **18**B depict further details of a network portion of an example MABR network architecture of FIG. **1** for facilitating TSTV channels in a VR environment according to an embodiment for purposes of the present patent application;

FIG. **19** depicts further details of a TSTV system that may be used in association with the network portion embodiment shown in FIGS. **18**A-**18**B;

FIGS. **20**A and **20**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in an illustrative use case scenario involving time-shifting of one or more channels;

FIGS. **21**A and **21**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in another illustrative use case scenario involving time-shifting of one or more channels;

FIGS. **22**A and **22**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in yet another illustrative use case scenario involving time-shifting of one or more channels;

FIGS. **23**A and **23**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in yet another illustrative use case scenario involving time-shifting of one or more channels;

FIGS. **24**A and **24**B depict portions of a flowchart comprising various blocks, steps and/or acts that may be (re) combined in one or more arrangements that illustrate a process flow for delivering TS content to a VD screen according to an embodiment of the present invention;

FIGS. **25**A-**25**D are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate various TSTV-related control processes that may be effectuated according to one or more embodiments of the present invention;

FIGS. **26**A-**26**D depict portions of a flowchart comprising various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate an example channel annealing mechanism for selecting media content channel bitrates in view of time-shifting of select channels according to one embodiment of the present patent disclosure;

FIGS. **27**A-**27**C are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate additional TSTV-related processes that may be effectuated according to one or more embodiments of the present invention; and

FIGS. **28**A-**28**C are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements relating to a example process of starting a virtual TS session and requesting bitrates for a TS session according to an embodiment of the present invention.

DETAILED DESCRIPTION

In the following description, numerous specific details are set forth with respect to one or more embodiments of the present patent disclosure. However, it should be understood that one or more embodiments may be practiced without such specific details. In other instances, well-known circuits, subsystems, components, structures and techniques have not been shown in detail in order not to obscure the understanding of the example embodiments. Accordingly, it will be appreciated by one skilled in the art that the embodiments of the present disclosure may be practiced without such specific components. It should be further recognized that those of ordinary skill in the art, with the aid of the Detailed Description set forth herein and taking reference to the accompanying drawings, will be able to make and use one or more embodiments without undue experimentation.

Additionally, terms such as "coupled" and "connected," along with their derivatives, may be used in the following description, claims, or both. It should be understood that these terms are not necessarily intended as synonyms for each other. "Coupled" may be used to indicate that two or more elements, which may or may not be in direct physical or electrical contact with each other, co-operate or interact with each other. "Connected" may be used to indicate the establishment of communication, i.e., a communicative relationship, between two or more elements that are coupled with each other. Further, in one or more example embodiments set forth herein, generally speaking, an element, component or module may be configured to perform a function if the element is capable of performing or otherwise structurally arranged or programmed under suitable executable code to perform that function.

As used herein, a network element or node may be comprised of one or more pieces of service network equipment, including hardware and software that communicatively interconnects other equipment on a network (e.g., other network elements, end stations, etc.), and is adapted to host one or more applications or services with respect to a plurality of subscribers. As such, some network elements may be disposed in a wireless radio network environment whereas other network elements may be disposed in a public packet-switched network infrastructure, including or otherwise involving suitable content delivery network (CDN)

infrastructure. In still further arrangements, one or more network elements may be disposed in a cloud-based platform or datacenter having suitable equipment running virtualized functions or applications. Accordingly, at least some network elements may comprise "multiple services network elements" that provide support for multiple network-based functions (e.g., A/V media management, session control, Quality of Service (QoS) policy enforcement, bandwidth scheduling management, subscriber/device policy and profile management, content provider priority policy management, streaming policy management, network storage policy management, and the like), in addition to providing support for multiple application services (e.g., data and multimedia applications). Subscriber end stations, client devices or customer premises equipment (CPE) may comprise any device configured to execute, inter alia, a streaming client application and/or a HTTP download application for receiving live/stored media content from one or more content providers, e.g., via a suitable access network or edge network arrangement based on a variety of access technologies, standards and protocols. For purposes of one or more embodiments of the present invention, an example client device may also comprise a hardware platform for running networked or local gaming engines and related applications for effectuating virtual reality environments in a subscriber premises. Such client devices and/or CPE hardware platforms may therefore include portable laptops, netbooks, palm tops, tablets, mobile phones, smartphones, multimedia/video phones, mobile/wireless user equipment, portable media players, portable gaming systems or consoles (such as the Wii®, Play Station 3®, etc.) and the like that may access or consume live media content/services, stored content services or video on demand (VOD) services, time-shifted and/or place-shifted content services, etc. provided over a delivery network or a combination of networks for purposes of one or more embodiments set forth herein. Further, the client devices may also access or consume content/services provided over broadcast networks (e.g., cable and satellite networks) as well as a packet-switched wide area public network such as the Internet via suitable service provider access networks. In a still further variation, the client devices or subscriber end stations may also access or consume content/services provided on virtual private networks (VPNs) overlaid on (e.g., tunneled through) the Internet.

One or more embodiments of the present patent disclosure may be implemented using different combinations of software, firmware, and/or hardware in one or more modules suitably programmed and/or configured. Thus, one or more of the techniques shown in the Figures (e.g., flowcharts) may be implemented using code and data stored and executed on one or more electronic devices or nodes (e.g., a subscriber client device or end station, a network element, etc.). Such electronic devices may store and communicate (internally and/or with other electronic devices over a network) code and data using computer-readable media, such as non-transitory computer-readable storage media (e.g., magnetic disks, optical disks, random access memory, read-only memory, flash memory devices, phase-change memory, etc.), transitory computer-readable transmission media (e.g., electrical, optical, acoustical or other form of propagated signals—such as carrier waves, infrared signals, digital signals), etc. In addition, such network elements may typically include a set of one or more processors coupled to one or more other components, such as one or more storage devices (e.g., non-transitory machine-readable storage media) as well as storage database(s), user input/output devices (e.g., a keyboard, a touch screen, a pointing device, and/or a display), and network connections for effectuating signaling and/or bearer media transmission. The coupling of the set of processors and other components may be typically through one or more buses and bridges (also termed as bus controllers), arranged in any known (e.g., symmetric/shared multiprocessing) or heretofore unknown architectures. Thus, the storage device or component of a given electronic device or network element may be configured to store code and/or data for execution on one or more processors of that element, node or electronic device for purposes of implementing one or more techniques of the present disclosure.

Referring now to the drawings and more particularly to FIG. **1**, depicted therein is an example MABR communications network **100** where one or more embodiments of the present patent application may be practiced for facilitating delivery of media content to one or more virtual display (VD) screens of a virtual reality (VR) environment of a subscriber premises **102**. In the context of the present disclosure, an embodiment of the MABR communications network **100** may implemented as an end-to-end network architecture for delivering MABR media content (and advertisement content, where applicable) using any delivery infrastructures, e.g., a Digital Subscriber Line (DSL) architecture, a Data Over Cable Service Interface Specification (DOCSIS)-compliant Cable Modem Termination System (CMTS) architecture, a suitable satellite access architecture or a broadband wireless access architecture. By way of example and introduction, MABR streaming delivery is broadly set forth herein that is applicable to DSL architectures without necessarily being limited thereto. As will be seen below, content may be delivered using either multicast ABR techniques or unicast ABR techniques. In a unicast delivery, a subscribing receiver may be provided with a direct and unique two-way path through the delivery network all the way back to a serving media server supplying the required data stream. The main streaming activity is managed on a one-to-one basis between the receiver and the source server in a communication session. The network between the source server and receiver may typically comprise a series of intermediate servers installed at network nodes, which may not be directly involved in the service but only support the transfer of a packet stream. Typically, the protocols used to support the transmissions are simple forms of Internet Protocol (IP) itself augmented by one or more higher layer protocols to provide flow control. These protocols extend across the span of the network connection between the source server and a given receiver.

A unicast system can support ABR streaming, which allows some form of rate adaptation. A given service may be encoded at a selection of different bitrates (known as representations), with synchronised boundary points at defined locations (e.g., every 50 frames). For each representation, content between successive boundary points is converted into a discrete file. Clients fetch a segment of one of the representations in turn. If a higher or a lower bit rate is required, the next segment is fetched from one of the other representations. The segments are constructed such that there is no discontinuity in decoded pictures/audio if the client switches between representations at the boundary points. This system may require a unicast two-way path between source and receiver to request files and deliver the requested files.

Multicast delivery makes more efficient use of bandwidth by sharing content streams among several receivers, wherein the content may be provided with or without rate adaptation. Intermediate network elements (e.g., routers or switches) are now more closely involved in the service delivery such that

some control and management functions are delegated from the source server. This control is supported by more extensive protocols devised for this type of application such as, e.g., Protocol Independent Multicast (PIM) and Internet Group Multicast Protocol (IGMP). When a receiver requests a given media item, the network router system finds an existing stream of that content already in the network and directs a copy of it to that receiver from a serving cable headend, a video head office or an appropriately proximal network node in an edge distribution network. The requesting receiver may be provided with the capability to join this existing stream under controlled conditions that do not adversely affect existing receivers. Any receiver in this group may also be provided with the ability to leave the stream, or pause its consumption, without affecting the others. Additionally, there may be an implementation where a video pipe delivering services to a premises is operative to deliver content to one or more progressive download clients of the premises that are designed to receive the video in bursts.

Subscriber premises **102**, which is served by a suitable broadband pipe **110**, is illustratively shown in FIG. **1** as having a plurality of client devices **104**(N), some of which may consume multicast/unicast content in normal real-life consumption scenarios, wherein one or more client devices may comprise STBs respectively coupled to or otherwise integrated with at least one display device (not specifically shown) and/or associated DVR/PVR or some other internal/external storage **106** for recording program content. Additionally, one or more client devices may be configured to effectuate a virtual reality (VR) environment **105** in conjunction with suitable ancillary devices such as VR headsets, etc., wherein a plurality of virtual display (VD) screens **107-1** to **107**-M may be effectuated that receive media content channels via HTTP downloading for purposes an embodiment of the present invention. Accordingly, the client devices **104**(N) may include STBs, standalone DVRs, or other standalone recording/storage devices, as well as VR-capable laptops, PCs, smartphones, tablet/phablet devices, and gaming consoles (collectively exemplified by VR apparatus (VRA) **109**), which may be provided as part of a premises network disposed in the subscriber premises **102**. As the MABR program content may be encoded using different encoding schemes (i.e., source encoding), the client devices may be configured to operate with one or more coder-decoder (codec) functionalities based on known or hereto unknown standards or specifications including but not limited to, e.g., Moving Pictures Expert Group (MPEG) codecs (MPEG, MPEG-2, MPEG-4, etc.), H.264 codec, High Efficiency Video Coding or HEVC (H.265) codec, and the like, in order to receive and render various types of programming content that is delivered as a plurality of service channels.

As noted, a premises network (not explicitly shown) may be disposed in the premises **102** for inter-operatively connecting the client devices, including the VR-capable devices, to a suitable premises node or element **108** such as a DSL router/gateway or a modem that is operative to effectuate communications (including bearer and signaling traffic) with respect to the client devices of premises **102**. Regardless of the exact composition of the client devices, such a premises network may be implemented using any suitable wireless or wireline network technologies. Although not specifically shown in FIG. **1**, it should be appreciated that premises **102** may also include other devices that may consume bandwidth for other data and voice communications as previously noted. Accordingly, the total bandwidth of subscriber premises pipe **110** may be apportioned between or allocated to a virtual video pipe for HTTP-based delivery of managed service channels to the VD screens **107-1** to **107**-M of the VR environment **105**, in addition to data and voice pipes. Furthermore, as will be set forth in detail further below, bandwidth of the managed video pipe used for delivering media content channels to the VD screens may be dynamically allocated based on selecting particular single bitrates from the available multiple bitrate representations the channels according to one or more embodiments of the present invention.

For purposes of the present patent application, embodiments concerning media content delivery and bandwidth control relative to MABR media content provided to the VD screens **107-1** to **107**-M in the premises VR environment **105** will therefore be described in detail hereinbelow, without taking further reference to the other client devices of the premises **102** unless otherwise noted.

As noted above, subscriber premises **102** may be served in an example implementation via an access network architected over DSL infrastructure including DSL Access Multiplexer (DSLAM) nodes, broadband network gateways (BNGs), and the like. Accordingly, the subscriber premises bandwidth pipe **110** may be disposed between subscriber premises gateway (GW) node **108** and an access aggregation node **112** such as a DSL Access Multiplexer (DSLAM) node that may be coupled to a suitable IGMP switch or router **114** (e.g., IGMPv2/v3-capable Gigabit Ethernet (GigE) multicast router) via a BNG node (not specifically shown in this FIG.). An ABR management agent entity **113** provided with GW **108** is operative for effectuating suitable IGMP Leave/Join messages, in conjunction with additional functionalities or structures set forth in detail further below, with respect to joining, leaving or changing various multicast streams, as well as bitrate selection and dynamic bandwidth allocation corresponding to the service channels available to VD screens **107-1** to **107**-M of the subscriber's VR environment **105**.

One or more ABR encoders **124**, which may be provided as part of a multicast stream formation (MSF) functionality in one example embodiment, are operative to receive a plurality of channel source feeds **126-1** to **126**-N corresponding to a group of service channels that may be provided as MABR channels having segmented streams at different bitrate representations as will be described in detail below. Typically, the ABR encoder **124** receives live feeds from appropriate communications networks, although it is possible in an alternative or additional arrangement for a file-based streamer to read the content files from a disk, e.g., network storage **121**, and stream the content streams via a network to the ABR encoder **124**. Accordingly, the channel source feeds may comprise a variety of content or programs, e.g., pay TV broadcast programs delivered via cable networks or satellite networks, free-to-air satellite TV shows, IPTV programs, time-shifted/place-shifted TV (TS/PSTV) content, and the like. Regardless of how channel source feeds are generated and provided to the ABR encoder **124**, a segmentation and gapping (SAG) unit **120** is configured to receive a plurality of encoded MABR streams for each service channel from the MABR encoder **124**. As noted, each encoded MABR stream corresponds to a particular bitrate representation (e.g., 10 megabits per second (Mbs or Mbps) to 500 kilobits per second (Kbs or Kbps)) that correspond to various levels of video quality or resolutions) of a specific service channel to which a subscriber may tune for watching on a particular VD screen of the VR environment **105**. SAG element **120** is operative to generate a

segmented and gapped MABR stream for each encoded MABR stream of each service channel in a gapping functionality that may also be provided as part of an MSF module or node described in further detail below.

In one example additional or alternative implementation, a DVR recording scheduling node, subsystem or element **122** may be optionally disposed in the MABR communications network environment **100** that is operative to interface with one or more client devices of the premises **102**, e.g., interfaces **130**A/**130**B, in order to facilitate recording of TV channels that may be presented for viewing on a VD screen. By way of illustration, an example EPG may be provided as or via an interactive graphical user interface from which a TV program may be selected for recording, which may also be available on a VD screen in one example arrangement.

In accordance with further teachings of the present invention, a multicast ABR bandwidth and QoS policy manager node, element or subsystem **128** may be provided for interfacing with the multicast VMA (MVMA) functionality **113** executing at GW **108**. In one embodiment, the MABR bandwidth/QoS policy manager **128** may be configured to provide bandwidth allocation policy information to VMA **113** via suitable interfaces **132** for effectuating channel joining, channel changing, etc. at appropriate bitrate streams or representations as will be set forth hereinbelow. In addition, a MABR back office node or element **134** may be coupled to MVMA **113** for providing information regarding all multicast services as well as corresponding MABR bitrates for each service supported in the network **100**. According to the teachings of the present invention, MVMA **113** is operative responsive to the bandwidth allocation/update messages from various entities for joining of multiple service channels being provided to the subscriber premises, including MABR streams selected for downloading to the VD screens at selected bitrates based on channel packing techniques applied to the managed MABR pipe portion of the subscriber premises bandwidth pipe. As part of channel joining operations, MVMA **113** may therefore be configured to receive the segmented and gapped MABR streams for each service channel from SAG **120** and join the MABR streams at select bitrate representations for facilitating downloading operations by an HTTP server, as will be set forth in additional detail below.

Depending on implementation, one arrangement may involve providing the multicast ABR VMA (MVMA) functionality at a location upstream from IGMP router **114**. Further, in such an arrangement (also referred to as "network agent implementation"), the MVMA functionality may be provided as a virtual machine function (i.e., in a virtualized environment running on a physical/hardware platform) instantiated at a network node or element. In a still further arrangement, the MVMA functionality may be provided in a cloud or at a CDN edge node. Regardless of where it is implemented, the MVMA functionality has the overall responsibility for joining multicast service channels, including channels designated for showing on VD screens of the subscriber's VR environment **105** at appropriate timing reference points, and having suitable bitrate representations selected in order to effectuate subscriber pipe bandwidth management in an optimal manner. Accordingly, one skilled in the art will recognize that although in the illustrated arrangement of FIG. **1**, the MVMA functionality **113** is provided at the premises gateway (also referred to as "gateway agent implementation"), the teachings of the present application are not necessarily limited thereto.

Accordingly, regardless of where an example MVMA node is implemented, it is generally configured to receive appropriately joined segmented/gapped MABR streams corresponding to the multicast service channels from SAG functionality **120**. Furthermore, SAG functionality **120** and encoder functionality **124** may be combined into an integrated MSF functionality as noted above. Attention is now directed to FIG. **14** that depicts a block diagram of an apparatus **1400** operative as a multicast ABR encoder and gapper for segmenting or packaging content channels for purposes of an embodiment of the present patent application. Apparatus **1400** is advantageously configured for creating a set of segmented stream representations and forming bursts with respect to a media service, which segmented streams may be provided with suitable inter-segment gaps that allow channel operations such as channel joining, channel leaving, switching, splicing in or splicing out, channel (re)multiplexing, etc. as part of downstream operations (e.g., at MVMA functionality **113** in conjunction with IGMP switch **114**). In an example implementation, apparatus **1400** may receive an input feed **1402** of content per service (e.g., corresponding to any of channel source feeds **126-1** to **126**-N in FIG. **1**) at an input block **1406** that fans the feed to a plurality of encoders/transcoders **1408-1** to **1408**-N, which generate, in parallel, a set of representations of the content at different bitrates. The representations can differ in video resolution depending on the bitrate of encoding. A timing generator **1404** outputs a signal that determines the boundary point of the segments. For example, this functionality may output a signal once per 50 frames (2 seconds), or at any other suitable time interval. The signal output by generator **1404** is applied to all of the parallel encoders **1408-1** to **1408**-N for that service. Advantageously, the set of coders **1408-1** to **1408**-N can close a Group of Pictures (GOP) and a boundary point insertion unit **1412** can insert in-band signaling such as a Random Access Point (RAP) and a Boundary Point (BP). The outputs of the set of coders **1408-1** to **1408**-N are the set of representations **1410** which have time-aligned and/or frame-aligned segments. The representations **1410** are applied to a burst generator unit **1418** that creates the bursts separated by window periods (e.g., on the order of tens or hundreds of milliseconds). In operation, unit **1418** may be configured to play out data at a higher bit rate than the bit rate at which data was received to create the bursts and is operative to recognize the start and end of segments in the representations **1410** by detecting suitable signaling markers (e.g. the in-band BP signaling inserted by the encoders).

Multicast address information may be added at an IP adaptation stage, which can occur at, for example, a GW node hosting the MVMA functionality or at a node further upstream (e.g., in a network node implementation). Multicast IP datagrams have a destination IP address that is set to be in a range reserved for multicast. In FIG. **14**, reference numeral **1424** refers to a bundle of IP-addressed streams generated by the apparatus **1400**. It should be appreciated that the apparatus shown in FIG. **14** can operate on data at one of various possible levels. In one advantageous scheme, data may be encoded into Transport Stream (TS) packets at a normal rate and the burst generator unit **1418** operates on TS packets. Transport Stream packets can be adapted into IP packets before burst generator unit **1418** at adaptation block **1416**, or after unit **1418** at adaptation block **1422**. Another alternative is to form bursts before any packetization (at TS or IP level), but this may be less desirable.

FIG. **14** further illustrates several possible places where end of burst signaling can be added. Each encoder **1408-1** to **1408**-N can include an end of burst signal insertion unit **1414** that adds an information element indicating the end of

a burst into the encoded data, which includes a header of the TS packets. Alternatively, the burst generator unit **1418** can include an end of burst signal insertion unit **1420** arranged to insert an information element indicating the end of a burst into each of the bursts. Where end of burst signaling is provided as a multicast (with same or different address), the multicast can be generated at the edge network node.

Typically, a network operator may receive a media content service feed from a service provider, which may then be converted to streams or channels having the right characteristics for the edge distribution network and end users of the network. Although FIG. **14** shows a set of encoders/transcoders **1408-1** to **1408**-N configured to operate upon an input data stream **1402** to form the multiple representations at different bitrates, such a stage may be bypassed where a set of representations at different bitrates already exist (e.g., by way of a separate encoder **124** as shown in FIG. **1**). Accordingly, it should be understood that multiple representations for a media content service channel can be generated at a point of origin into the MABR communications network or could be supplied by a service provider, wherein the multiple representations can include various quality definitions, e.g., Standard Definition (SD), High Definition (HD), Ultra HD, etc., of the same content. A skilled artisan will recognize that the duration of the window period (e.g., 200 to 300 milliseconds or thereabouts) introduced in a segmented stream is of sufficient magnitude for a multicast receiver to leave one representation of the stream and join a different representation at a different bitrate or an entirely different media stream, at appropriate timing reference points, e.g., stream access points (SAPs), which may be accomplished by issuing appropriate IGMP Leave and Join message, without incurring too much latency or delay in VR environments.

A potential consequence of adding window periods or gaps to the transmitted streams is that the flow of content may become jittered beyond the level that normal packet transmission produces. This can be accommodated by buffering provided within an intermediary reception apparatus, e.g., MVMA functionality **113**. The window period duration will influence the amount of jitter produced and so there is an optimum size that is related to the worst-case response times of the chain of routers/servers delivering the content. This time is taken for switches to recognize and implement all those steps that are required to keep the stream flowing, including the potential need for the multicast content to be found at or near the source server. For segment durations of the order of about 2 seconds, a possible value of the window period is around 330 milliseconds. The window size is a function of the responsiveness of the network to support multicast Leave and Join functions and it will be appreciated that the window period can be modified to a higher or lower value. More generally, the window period could have a value selected from the range of 0.1 ms and 10 seconds and, more advantageously, the range 10 ms-350 ms. As switches and routers increase in performance, it is possible that the window duration can be reduced to the lower end of the ranges stated above. In one implementation of the MVMA functionality, a 300 ms gap and suitable buffering may allow MVMA **113** (in the gateway agent implementation shown in FIG. **1**) to perform IGMP Leave and Join operations for seamless switching of regular multicast service channel content with respect to channel tuning/change requests as well as tuning to appropriate service channels at scheduled recording times as per requests from VR-capable client devices. Whereas the segmented/gapped MABR streams for various service channels are received at receive ports of the MVMA node with multicast addresses changing on the fly, the downstream port addresses (i.e., to the premises) are fixed, corresponding the various service channels, to which IGMP Join operations are ultimately propagated from the subscriber stations. Additional details regarding multicast segmented stream formation and channel joining/leaving techniques may be found in commonly owned PCT Application No. PCT/EP2012/070960, titled "A METHOD AND APPARATUS FOR DISTRIBUTING A MEDIA CONTENT SERVICE", filed Oct. 23, 2012, in the name(s) of Anthony Richard Jones, now published as WO2014/063726, incorporated by reference herein.

FIG. **2** depicts a network portion or subsystem **200** that may be arranged as at least part of an apparatus for facilitating delivery of media content as multi-bit gapped MABR segment streams in a MABR network architecture **100** of FIG. **1** according to one embodiment. In particular, subsystem **200** shows further details of an example implementation of SAG functionality **120** that is operative to generate a set of gapped streams (e.g., having ~300 ms gaps between SAPs of two segments (i.e., inter-SAP gap)) with respect to a particular service channel feed **202** that may be tuned to by a user operating a VR-capable client device of the subscriber premises **102** for presentation on a VD screen, wherein the channel feed **202** is illustrative of the service channels **126-1** to **126**-N shown in FIG. **1**. Consistent with the description above, the channel feed **202** may be received by MABR encoder/transcoder **124** for generating a plurality of encoded (and unsegmented) streams encoded at, e.g., 10 Mbs to 500 Kbs (i.e., multiple bitrate or multi-bitrate representations) as exemplified by reference numeral **220**, which may be processed as corresponding segmented streams **222** by the segmenter/packager **120**.

In one embodiment, SAG **120** may be configured to transmit all possible bitrates for services that are identified as multicast services to the next element downstream as per the standard multicast operations. Where the MVMA functionality is embodied in a network agent implementation, it is typically the downstream recipient of the regular multicast gapped/segmented streams **222** with respect to each service channel. In a gateway agent implementation, such streams are provided to the IGMP router **114**, as shown in the illustrative arrangement of FIG. **2**, wherein the IGMP router **114** may pass along streams for only those channels that are active, as shown by example downstream bundle **224** propagating towards DSLAM node **112** (and ultimately to the premises gateway node's MVMA functionality, which issues suitable Join/Leave messages with respect to the particular segment streams having the select bitrate representations). As will be described below, the MVMA functionality is modulated based on, inter alia, messages provided by the VR-capable device effectuating the VR environment **105** in reference to the subscriber's field of view within the VR environment **105** relative to the placement of VD screens **107-1** to **107**-M therein.

FIGS. **3**A-**3**C depict further details of a network portion comprised of sub-portions **300**A-**300**C of an example MABR network architecture of FIG. **1** for providing gapped MABR segment streams as media content channels to a plurality of subscriber premises via respective broadband delivery pipes **318-1** to **318**-N according to an embodiment for purposes of the present patent application. Various video source feeds **302-1** to **302**-N are representative of N media content channels or service channels that are provided to corresponding ABR encoders **304-1** to **304**-N (which in an example implementation may be integrated into one or more encoder blocks), that in turn encode multi-bitrate represen-

tations of each service channel (e.g., 6 Mbs to 400 Kbs), similar to the description provided hereinabove. A segmentation/gapper unit **306** comprises a segment cache **308** that stores the segmented streams may be provided with a suitable gapper **310** as described previously. For example, N gapped services in multiple representations are illustrated wherein an example segment size or duration may comprise 4 seconds, with 300 ms gap between SAPs. IGMP **312** and BNG **314** (also referred to as a broadband remote access server or BRAS) are operative to join different representations of each service to DSLAM **316**, which is operative to effectuate a point-to-point communications link to each subscriber premises via respective pipes **318-1** to **318**-N. It should be noted that each pipe carries only one single bitrate per active service channel (i.e., the media content channel being viewed on a VD screen). Accordingly, each broadband pipe may be carrying different services (as single bitrate segmented streams) and at different bitrates to the subscriber premises.

FIGS. **4**A and **4**B depict a system diagram of a gateway implementation **400**A/**400**B of an embodiment of the present invention wherein a block diagram of a subscriber premises gateway or node **402** may be configured according to the teachings of the instant patent application. Broadly, GW **402** includes a VMA node or functionality **420** (analogous to MVMA **113** of FIG. **1**) that is operative to generate a single bitrate manifest (in order to prevent the client device from choosing the bitrates as is typical in an ABR environment), and to facilitate delivery of the streams, segment by segment, requested by the clients while controlling the bitrate(s), via HTTP-based downloading. Thus, an embodiment of GW **402** of the present invention may be advantageously configured for delivering select single bitrate representations of the media content channels to VD screens of a subscriber's VR environment in an example architecture without the greedy behavior associated with typical ABR clients (which can cause undesirable latency/lagging issues in VR environments).

It will be recognized that according to one embodiment the MABR VMA functionality **420** may be realized as a virtual function or virtual machine on a host hardware/software platform (e.g., GW **402**) or in a cloud data center. As described previously, a plurality of MABR gapped/segmented streams comprising various bitrate representations of multicast service channels may be received by node **402** at corresponding multicast IP addresses, which may be changing on the fly depending on the IGMP Join/Leave operations. A segment cache **424** is provided wherein a plurality of segments corresponding to one or more active multicast service channels having potentially different bitrate qualities may be stored. A virtual pipe or stream bandwidth manager **428** that may be part of an overall bandwidth and policy management module **426** is operative in conjunction with the segment cache **426** to manage a subscriber premises bandwidth pipe or pipe portion allocated for multicast IPTV/video services delivered to VD screens via HTTP download/delivery, wherein suitable IGMP Join/Leave messages may be generated/provided via interface **425** with respect to selected bitrate streams

By way of example, subscriber premises **404** illustrates a VR device **408** operative with a VR-capable client (not specifically shown) that can create or otherwise effectuate a VR space **406** according to known or heretofore unknown VR technologies, wherein virtual TV screens **409-1** to **409-5** (e.g., representative of VD screens **107-1** to **107**-M shown in FIG. **1**) are illustrated. In accordance with the teachings of the present invention, the virtual pipe and stream bandwidth manager **428** is operative to effectuate channel/stream joining and leaving operations with respect to suitable bitrate representations of gapped service channel streams under IGMP Join and Leave operations responsive to, for example, stream weight updates received from the VR device **408** via interface **405**. An ABR manifest generator **430** is configured for generating a manifest **411** indicating single bit representations of each of the joined or active media content channel segments stored in the segment cache **420** of the gateway node **402**, which manifest may be provided via interface **407** to the client/VR device **408**. A HyperText Transfer Protocol (HTTP) server **432** is configured to deliver segments of the media content channels at respective single bitrates selected based on a channel bandwidth annealing mechanism using stream weight updates received from the VR device **408**. By way of a non-limiting example, suitable http-based request and response messages (e.g., http get requests) may be generated for obtaining media content segments for presentation on the VD screens. In one arrangement, single bitrates may be selected for optimally allocating the bandwidth of the managed video pipe serving the virtual TV screens of the VR environment based on a channel annealing mechanism as will be set forth in detail below.

Turning to FIG. **5**, depicted therein is an example VR environment effectuated by a VR device of a subscriber for presenting a plurality of VD screens according to an embodiment for purposes of the present patent disclosure. GW **502** associated with subscriber premises **500** is served by a delivery pipe **504** for providing media content channels to VD screens **522-1** to **522**-K effectuated in a VR theater or environment **520**. As one skilled in the art will recognize, virtual reality (or VR) is a computer technology that uses software-generated realistic images, sounds and other sensations to replicate a real environment or an imaginary setting, and simulates a user's physical presence in the simulated environment to enable the user to interact with any portion of the space. A person using virtual reality equipment is typically able to "look around" the artificial world, move about in it and interact with features or items that are depicted. Virtual realities artificially create sensory experiences, which can include sight, touch, hearing, etc. and may simulate real world scenarios such as, e.g., virtual coffee shops, virtual sports bars, multi-screen theaters, in addition to 3-D environments such as virtual worlds created for gaming. An example VR apparatus may comprise a CPE hardware platform **506** served by GW **502**, such as a gaming console, laptop, or a smartphone, for example, that executes one or more VR-based gaming or media applications to provide suitable signals to one or more VR-enabling devices such as a display device **516** mounted to or on a user's head **518**. Additional examples of such devices may comprise visors, goggles, wired headgear or helmets, masks, etc. that can display or effectuate an immersive VR space surrounding the user. In an example display device, there maybe additional instrumentation such as a gyroscope, accelerometer and a magnetometer, etc., to facilitate head tracking, i.e., when the user **518** moves her head, the field of view around the simulated space may move accordingly. Thus, in a head-tracking VR headset, the cone of view or field of view in front of the user shifts as the user looks up, down and moves side to side or angles her head. An example system may include the so-called 6DoF (six degrees of freedom) arrangement that can plot the user's head in terms of x, y and z axes to measure head movements forward and backwards, side to side and shoulder to shoulder, also known as pitch, yaw and roll, which may be used for tracking the user's point of view within the VR space.

By way of illustration, CPE **506** may be embodied as a platform **508** including one or more processors **526**, volatile and nonvolatile/persistent memory **524**, input/output (I/O) interfaces **530** (e.g., touch screens, gaming controllers, hand-tracking gloves, etc.), as well as one or more media/gaming applications **528** that can effectuate VR space **520** for the user **518** wearing head-mounted display (HMD) **516**. In one example arrangement, HMD **518** may be wirelessly coupled to CPE **506** via wireless interface **512**. Additional VR-capable CPE **514** (e.g., a tablet/smartphone) may also be separately or optionally provided. Example VR apparatus **514/516** operating in conjunction with HMD **516** may be operative to effectuate VR space **520** that is an immersive VR environment in which the user **518** can move her point of view in full 360° in one of a vertical plane, a horizontal plane, or both planes, defined in the VR environment. In an additional or alternative arrangement, VR apparatus **514/516** operating in conjunction with HMD **516** may be operative to effectuate VR space **520** that may be immersive but the user **518** can only move her point of view in less than 360° along any one of the axes.

As noted above, VR space **520** may simulate a VR environment having multiple VD screens (VDSs) **522-1** to **522**-K that may comprise one or more virtualized TV screens, virtualized gaming monitors, virtualized tablets, virtualized phablets, virtualized computer monitors, and virtualized projector screens, that may have various sizes, shapes, form factors, and aspect ratios, wherein each may be adapted to display a media content channel according to the corresponding VR media/gaming applications being run by the VR apparatus **514/516**. In one arrangement, example VD screens may be presented or placed within the VR space across a front wall, sidewalls, top ceiling and a back wall, as well as along a floor, at different distances (e.g., predetermined) from the viewer's head and from one another, to simulate a variety of real-world settings and scenarios, e.g., a sports bar with several TV screens showing various TV channels. Further, such VD screens may be "turned on" or "turned off" in a VR application, e.g., by the subscriber or the subscriber's guest (in a shared VR space, for instance). One will recognize that such media content channels may comprise live TV channels, time-shifted (TS) TV channels, place-shifted (PS) TV channels, gaming channels, VOD channels and/or public service announcement channels. Additionally, a plurality of decoder buffers **525** may be provided as part of an example VR platform corresponding to the plurality of media content channels being shown on the VDSs of a VR spatial environment.

A movement detection and stream weight assignment module **510** is operative to detect a movement in a point of view of the user/subscriber **518** with respect to the VR space **520** and assign/adjust weights of the VDSs and associated media channels based on the VD screens' placement relative to where the subscriber's point of view is and/or whether the VD screens are within the subscriber's field of view/vision, as the subscriber **518** shifts her gaze from one VD screen to another within the VR space **520**. As noted above, the stream weights or their updates may be advantageously provided to GW **502** for facilitating dynamic bitrate control as will be described in detail further below.

Broadly, an example embodiment of the present invention relates to adjusting, updating, (re)assigning stream weights or priorities given to or otherwise associated with media content channels showing on VD screens of a VR environment based on where the user/subscriber is looking, and utilizing the updated or (re)assigned stream weights in a channel annealing mechanism to determine or otherwise select single bitrates that optimize the bandwidth allocation of a media pipe serving the VR environment. In accordance with the teachings of the present invention, movement in the subscriber's point of view may be determined by the subscriber's VR headset or in combination with the VR platform responsive to the subscriber's head movement. In some arrangements, ocular movement may also be monitored and used in combination with the head movement for updating the stream weights. If a VD screen is close to where the subscriber is gazing, the media content channel showing on that VD screen may be assigned or updated to have a higher weight. On the other hand, if a VD screen is away from the subscriber's gaze, the media content channel associated with that VD screen may be given a lower weight. Further, if a VD screen is outside the subscriber's field of view or vision (FOV), e.g., beyond peripheral vision, the media content channel may be given a lowest minimum weight in order to conserve the bandwidth of the MABR media pipe serving the VR environment. In still further embodiments, media content channels on the VD screens that are completely outside the subscriber's FOV may be suspended and time-shifted for playback at a later time when the VD screens do come into the subscriber's FOV as the subscriber scans the VR space and gazes across the multiple VD screens to watch different channels, e.g., depending on audiovisual cues provided in a program. Further details regarding these and other embodiments will be described below by taking reference to the remaining drawing Figures of this disclosure.

FIGS. **6**A and **6**B are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements, with or without additional flowcharts of the present disclosure, for facilitating a bitrate control process in delivering media content channels to VD screens according to an embodiment. Process **600**A shown in FIG. **6**A commences with detection of a movement in a subscriber's point of view or line of view within a VR environment comprising a plurality of VD screens (block **602**). Angular distances of the various VD screens may be measured, e.g., in radians or degrees, from a reference axis or line within a field of view of the VR environment (block **604**). Given the 3D immersive VR environment, which may be spherical or otherwise curvilinear, the field of view of the subscriber may be partitioned into various sectors or cones (depending on whether angles in 2D or 3D are being measured) with respect to the reference axis. A predetermined (re)assignment of weights or updates may be provided (block **606**) for the VD screens and corresponding media content channels depending on where the VD screens are within different sectors of the FOV, with the media content channels on the VD screens closest to the reference axis being accorded a highest value. As the VD screens that are progressively farther from the reference axis (either in horizontal or in vertical plane) capture less attention of the subscriber, the media content channels showing thereon may therefore have progressively lower weights. In one embodiment, even those VD screens that are outside the subscriber's FOV, e.g., those that are behind the subscriber in the VR space, may be given a non-null weight (i.e., non-zero weight) so as to ensure that all the bandwidth of the media pipe is allocated. Thereafter, the assigned/updated weights may be provided by the VR device/headset to a bandwidth annealing mechanism executing at the gateway for facilitating selection of a single bitrate per media content channel (from the available multi-bitrate representations), e.g., allocation or reallocation of bandwidth, as set forth at block **608**.

In another embodiment, process **600**B shown in FIG. **600**B involves assigning a null weight to the media content

channels that are on VD screens determined to be completely outside the subscriber's FOV (block **622**). Such null-weighted media content channels may be time-shifted (block **624**) according to the teachings of the present patent disclosure. Weights associated with the remaining non-time-shifted media channels may be used in channel annealing for selecting proper bitrates (i.e., selecting a single bitrate representation per media content channel), as set forth at block **626**, whereupon the suitable bitrate stream may be joined by the gateway and the segments thereof may be cached for downloading to the VD screens via HTTP delivery. As and when the subscriber's point of view may be reoriented within the VR space, one or more TS media content channels may resume playback, wherein the bandwidth may be reallocated based on the reassigned or updated weights provided by the VR device (block **628**), which will be described in additional detail further below.

FIG. **7** is a flowchart of various blocks, steps and/or acts that may be (re)combined with additional flowcharts of the present patent disclosure in one or more embodiments for facilitating a bitrate control scheme **700** in additional detail. At block **702**, a movement in a point of view of a subscriber in relation to a first reference axis with respect to the VD screens' placement within a VR environment may be detected, determined or otherwise obtained, e.g., using various known or heretofore unknown tracking technologies operative in a VR application. One skilled in the art will recognize that in one embodiment when the VR environment is first effectuated with a number of VD screens presented/placed at several locations within the VR space, the subscriber's initial gaze may define a first reference axis in the 3D scenario simulated in the VR environment. Further, a first reference axis may be any arbitrary, initial line of view or sight of the subscriber (e.g., at any time during a VR session) from which the subscriber's point of view moves within the VR spatial environment as her head moves (e.g., by a designated amount and/or within a predetermined amount of time), resulting in a second reference axis within the VR environment wherein each VD screen is configured to receive a media content channel. At block **704**, angular distances (e.g., either 3D or 2D angles) of each of the VD screens relative to the second reference axis may be computed using applicable curvilinear geometries (e.g., spherical, ellipsoidal, 3D-parabolic spaces, etc.) relative to creating the simulated VR spatial environment. Responsive to the determination of the angular distances (which may be computed along the vertical and/or horizontal planes, as noted previously), stream weights, priorities or other metrics (e.g., relative or otherwise) may be assigned to, initialized and/or updated for each of the media content channels based on the angular distance of the corresponding VD screens relative to the second reference axis (block **706**). One skilled in the art will recognize that partitioning of the VR spatial environment based on such angular distances relative to a reference axis may be effectuated at varying levels of granularity. Further, the stream weights may be determined, configured or modulated based on subscriber, operator and/or content provider policies as well in some example embodiments. As noted previously, the subscriber's VR device is operative to provide the updated/assigned stream weights to a gateway node serving the subscriber premises (block **708**), preferably sending only those updates/weights that have changed since prior updating (e.g., a "delta" compression may be applied), in order to minimize the control communications overhead. Responsive to the received stream weight updates, bandwidth of a managed bandwidth pipe may be (re)allocated based on the relative weights of the media content channels for delivering the media content channels to the subscriber's VR environment (e.g., by selecting a single bitrate of the MABR channel segments for each media channel responsive to a channel packing or bandwidth annealing mechanism), whereupon appropriate manifest(s) may be provided to the VR device, as set forth at block **710**.

One skilled in the art will further recognize that although angular distances or deviations are specifically set forth herein, suitable metric distances (e.g., distances between two lines projected on a curved space) may also be used in weight assignment computations in an alternative embodiment of the present invention.

An example channel annealing scheme of the present invention is operative to choose or converge to a model in which bandwidth of a managed MABR pipe serving the VD screens of a VR environment may be redistributed optimally among the various media content channels sharing the assigned pipe based on the updated stream weights that may be continually changing responsive to the head movements of the VR subscriber. Accordingly, an already existing channel of the managed MABR pipe may experience lowering of its bandwidth, e.g., all the way down to its default value or to some other intermediate value in order to fit within the pipe, depending on its weight. Additionally or alternatively, bandwidth of the channels that are not being watched (e.g., in the context of time-shifted media channels) may be repurposed or reclaimed in order to improve the quality of the other channels of the media pipe. In one example implementation, selection of single bitrates of channels that can be packed into the media pipe serving the VR environment (which may be referred to as a "VR media pipe" that may be part of an overall subscriber premises bandwidth pipe), may be based on what is referred to herein as "inadequacy metric" that is used for selecting which streams are eligible for a bandwidth upgrade during annealing (i.e., iteratively changing bandwidth until no further optimal reallocation can be made). Basically, the inadequacy metric (IM) may be considered as a measure of how far out of balance an allocation to a stream is with regard to its priority/weight and the priority/weight of the other streams. Several examples of determining the inadequacy metric are listed below, although other measures of an imbalance can be used in practicing the disclosed embodiments. In one example methodology, given a list of channels and the ABR bandwidths available for each channel, the channels are first sorted by their priority (or other parameters relating to channel weight). A select minimum bandwidth version of the channel is added to the pipe plan. If the channel's minimum bandwidth does not fit (i.e., the pipe is overbooked), then it does not go in the pipe plan and the process moves on to the next channel for further iterations to see how much of an upgrade can be made to the pipe plan. As the channels in the list are sorted by the inadequacy metric, the process can start with the most inadequate channel allocation for attempting to upgrade the bandwidth to the next highest available version of a channel. As pointed above, if the upgrade does not fit within the pipe, that upgrade is skipped and the scheme proceeds to the next most inadequate channel. One skilled in the art should realize that a further variation in optimization may be where channels whose upgrade is impossible, they can be removed from consideration for the rest of the annealing loop. Once a channel is selected for upgrade, the inadequacy metric is recomputed and the scheme restarts the annealing loop, which may be configured to end when no channels can be upgraded to fit into the bandwidth allocation of a MABR virtual pipe serving the VR environment.

Several different inadequacy metrics can be implemented in practicing the foregoing scheme. In one example, the metric may be defined as a ratio of channel priority or weight to the bitrate, which guides the channel allocation toward a situation where each channel has a share of the bandwidth of the pipe proportional to its weight or priority. Another formulation could be a ratio of channel weight to its "quality", which can be quantized in some fashion (e.g., some function of the bitrate). A more complicated version might take into account the amount of action in a scene of the content, allowing bitrates to vary according to content. For instance, an action scene might get more of the pipe until the stream reaches a calmer moment in the content, at which point it returns bandwidth to the other streams in the pipe. In a still further variation, the IM may be defined as a function: IM=1/rate||weight, where || means a relative comparison of entities having different components.

For example, when comparing two metrics such as a**1**||b**1** and a**2**||b**2**, we compare the first parts first. If the first parts are unequal, we use the first parts to determine the comparison. If the first parts are equal, then we compare the next part to determine the comparison. So, by way of illustration, 1||100<2||1, but 1||100>1||5. Given that definition, it can be seen that the 1/rate||priority metric may result in all streams being allocated similar bandwidth. Regardless of how the IM is defined, each iteration of the annealing loop may be configured to upgrade the channel with the least bandwidth, and when there are multiple channels at the least bandwidth, it will upgrade the highest priority one first.

It should be noted that at least some of the bandwidth allocation and/or reallocation operations as well as channel joining operations responsive thereto set forth in the present disclosure make take place using a number of foregoing channel packing techniques that may involve pipe modeling schemes based on various pieces of parametric information such as composite device priorities (CDP), IM parametrics, and the like, potentially/preferably in conjunction with operator-, subscriber-, and/or content-based policy rules, wherein, for example, a new channel or an existing channel's particular bitrate representation may be added to the VR bandwidth pipe based on inadequacy metrics used for selecting which streams are eligible for a bandwidth upgrade during annealing (i.e., iteratively changing bandwidth until no further optimal reallocation can be made).

In some additional or alternative embodiments, a CDP-based channel packing may be employed in an annealing process involving MABR and/or UBAR video streams of the video pipe serving a subscriber premises. Additional details with respect to bandwidth divider implementations (e.g., dividing the total video pipe into a MABR portion and a UABR portion), as well as metrics-based stream management may be found in one or more of the following commonly owned U.S. patent application(s): (i) "UNICAST ABR STREAMING" (Ericsson Ref. No.: P43082-US1), application Ser. No. 14/246,920, filed Apr. 2, 2014, in the name(s) of Christopher Phillips et al., and (ii) MERGING MULTICAST ABR AND UNICAST ABR WITH PROGRESSIVE DOWNLOAD ABR IN A CUSTOMER PREMISES DEVICE WITHIN THE SAME VIDEO DELIVERY PIPE" (Ericsson Ref. No.: P43011-US1), application Ser. No. 14/246,880, filed Apr. 2, 2014, in the name(s) of Christopher Phillips et al., which are hereby incorporated by reference.

FIGS. **8**A and **8**B depict portions of a flowchart of various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate an example weight (re) assignment and/or weight updating process **800**A/**800**B according to one embodiment of the present patent disclosure. A skilled artisan will recognize that an embodiment of process **800**A/**800**B may be executed at or in combination with a subscriber's VR device based on detecting the subscriber's head movement or motion to decide or determine the weights associated with VD screens, using the underlying principle that VD screens being looked at directly have more weight than those in the peripheral vision, which in turn have more weight than those VD screens outside of view (i.e., non-visible VD screens). At block **802**, subscriber's VR device headset detects the subscriber's head movement. Responsive thereto, existing weights for all VD screens or TVs may be cleared (block **804**). In this example embodiment, accordingly, each time a head movement is detected, the weights are cleared or otherwise initialized for the subsequent process flow. At block **806**, the VR device calculates angles for each VD screen in relation of the subscriber's field of vision. A weight assignment/updating loop **808** is then executed for each VD screen, which involves the following in an example implementation. At blocks **810**, **812**, a degree field or a line of field from the center of a VD screen to the center of the VR display device (or some other reference point with respect to the VR display device) is calculated, which is compared against a cone of high visibility (e.g., within ±33 degrees), as set forth at block **814**. If the VD screen is within this cone, the media content channel associated with that VD screen is set to having a high weight value of 3.0. Otherwise, a series of further determinations may be made as set forth in FIG. **8**B (e.g., depending on the granularity of comparison cones or sectors used in partitioning the subscriber's field of vision), e.g., as set forth at blocks **818**, **826**. If there is no media content channel associated with a VD screen that is determined to be within a cone, weight assignment for that channel may be skipped (e.g., as set forth at blocks **820**, **824**, **825**, **828**). Otherwise, the media content channels of the VD screens located in different visibility cones or sectors are (re)assigned weights of 1.5 (e.g., a medium value, as set forth at block **822**), 0.75 (e.g., a low value set forth at block **830**), or 0.353 (e.g., a still lower value set forth at block **834** responsive to a determination at block **832**). After executing the weight assignment loop **808** for each VD screen, the flow exits (block **836**).

FIGS. **9**A-**9**D depict portions of a flowchart of various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate an example channel annealing mechanism **900**A-**900**D for dynamic selection of media content channel bitrates for optimizing bandwidth allocation of a subscriber bandwidth pipe based on stream channel weights/updates according to one embodiment of the present patent disclosure. At block **902**, a MABR bandwidth control agent or module (e.g., associated with a VMA) receives a Join or Leave request with respect to the media content channels being provided to the VR environment. If the request is a Leave request (as per determination at block **904**), the channel is removed from the target channel list used for annealing or channel packing (block **906**). If the request is a Join request, a further determination is made as to whether the stream segments are currently being delivered to the VD screen (block **908**). If not, a "listener" process or module may be started for monitoring dynamic bandwidth channel changes (block **910**). Otherwise, the channel is added to an active channel list (block **912**), which feeds into an MABR virtual pipe allocation mechanism for modeling or re-modeling bandwidth allocations for the active channels (block **914**). As set forth at block **916**, policy management

changes, if any, with respect to MABR virtual pipe allocation may also be input (e.g., from an MABR back office) into the modeling process.

The active channel list may be sorted, e.g., in a descending order based on a priority value, as set forth at block **915**, whereupon a packing iteration loop **918** may be executed for each active channel. First, a determination may be made whether the channel's lowest bitrate representation may be accommodated into the modeled or simulated bandwidth pipe (block **920**). If so, the channel is added to a list of applied channels along with a priority for that channel (block **922**). Otherwise, a further determination is made at block **924** as to whether there is a policy change to decreasing the pipe size. If so, the channel is added to a skipped channel list (block **928**). If the channel is not the same as the new/requested channel (block **926**), it is either added to the list of the applied channels (block **922**) or to the skipped channel list (block **928**).

In the exemplary embodiment of annealing flow **900**A-D shown in FIGS. **9**A-**9**D, a message or warning **940** may be provided with respect to each channel in the skipped channels list as set forth at a message loop process **938**. For each channel in the applied channels list, a weight application process **932** is executed wherein the weight/update received for the channel, e.g., via the listener monitoring (block **930**) provided for the joined channels, as set forth at block **934**. The applied channels list is then sorted based on the weights, e.g., in descending order, as set forth at block **936**, whereupon a bitrate upgrade loop process **942** is executed for each of the applied channels for arriving at an optimal bitrate for each channel. A determination is made whether the channel can be upgraded to the next highest bitrate using the existing MABR channel bandwidth allocation (block **944**). If so, the bitrate for that channel is changed to that next highest bitrate (block **946**). Otherwise, no upgrading is performed for that channel and process loop returns to the next channel in the weight-sorted applied channel list (block **948**).

Upon exiting the bitrate upgrade loop process **942**, an IGMP loop process **950** is performed, which involves determining whether the channel at the selected single bitrate representation is already connected to the correct IGMP node/port (block **952**). If so, that channel is skipped and the loop process iterates to the next channel's single bitrate (block **954**). If the channel at the selected bitrate is not already joined to the correct IGMP, an IGMP Join operation is performed to connect to the multicast stream having the calculated/selected multicast bitrate (block **956**). As one skilled in the art will recognize upon having reference hereto, the channel packing processes and/or sub-processes of flow **900**A-D may therefore involve one or more bandwidth pipe modeling and annealing mechanisms set forth hereinabove.

Turning to FIGS. **10**A/**10**B to **13**A/**13**B, various illustrative use case scenarios relating to example weight assignments and associated bandwidth allocations for media content channels in a VR environment or VR space having five VD screens are set forth therein, where a user/subscriber changes or shifts her viewpoints in relation to the VR spatial environment she is immersed in. In the example scenario **1000**A shown in FIG. **10**A, subscriber **1015** is disposed in a VR space **1002** having five VD screens or virtual TVs (VTVs) VTV-1 to VTV-5 (referred to by reference numerals **1004-1** to **1004-5**) at or along different "walls" of the space **1002**. As the subscriber **1015** is not viewing any VTVs directly, each of the VTVs is given a minimum available weight, e.g., 0.353. To prevent the VTVs from being completely blank, the user may be required to move her head in an example implementation. An example 360-degree field of view **1006** of the user **1015** may be partitioned into "high" weighted areas **1008**A/**1008**B, "medium" weighted areas **1010**A/**1010**B, "low" weighted areas **1012**A/**1012**B that are within the 180-degree peripheral field, the areas being demarcated in relation to the user's viewpoint line **1005** (directly looking ahead, for example, in the VR space **1002**). Non-visible areas **1014**A/**1014**B (e.g., behind-the-head areas) may be given lowest available weights possible in an example implementation of the scenario **1000**A set forth in FIG. **10**A.

Corresponding to the equal weight distributions provided to the VTVs in the scenario of FIG. **10**A, an example bandwidth allocation scheme **1000**B illustrates a subscriber bandwidth pipe **1052** provided to a gateway **1050** of subscriber premises that includes a VR device or apparatus **1056**. The total bandwidth of the subscriber pipe **1052** may be apportioned into a 10-Mbs managed MABR video pipe **1054**A serving VR environment **1002**, a data communications pipe **1054**B as well as a voice communications pipe **1054**C. Because of the equal weights accorded to VTVs, each channel (Channels 1-5) corresponding to the respective VTVs are allocated equal bandwidth (e.g., 1.8 Mbs, given the bitrate representations available for the channels), as shown by reference numerals **1056-1** to **1056-5**. It should be appreciated that such an allocation may leave some of the managed MABR video pipe to be unused, since the highest bitrate representation that can be used for each channel is 1.8 Mbs, which amounts to 9.0 Mbs usage in total. If a next highest bitrate were to be selected, e.g., 4 Mbs, the managed pipe would not be able to accommodate all five channels at the same equal weighting factors.

FIGS. **11**A and **11**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in another illustrative use case scenario **1100**A where a single VTV is directly viewed, another one in the peripheral vision and the remaining VTVs being unviewed. Reference numeral **1105** refers to a new viewpoint of the user **1015** in this use case scenario, with VTV-2 **1004-2** being directly viewed, VTV-1 **1004-1** being in a peripheral field. The weight assignment process of the present invention may therefore (re)assign or update the previously-assigned weights accordingly as shown in FIG. **11**A, which results in higher bandwidth allocation for the channel shown on VTV-2 because of its weight being updated to 3.0, e.g., 6 Mbs allocation as exemplified in the allocation scheme **1100**B of FIG. **11**B. VTV-1 being a peripheral screen gets an updated weight of 0.75, resulting in a smaller bandwidth allocation therefor. Still smaller bandwidth allocations may be provided for the remaining VTVs, each now having a weight of 0.353. It should be noted that in one example implementation, only those weights that are changed or updated to different values may be transmitted by the VR device **1056** to the gateway's bandwidth allocation/annealing mechanism in order to minimize the communications overhead.

FIGS. **12**A and **12**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in yet another illustrative use case scenario **1200**A where two VTVs (VTV-1 and VTV-2) are in direct view, VTV-3 is in peripheral view, and remaining VTV-4 and VTV-5 are not visible at all, taken in reference to a new line of view **1205** within the user's field of view **1207**. Corresponding bandwidth allocation scenario **1200**B accordingly illustrates 4 Mbs allocations for Channel 1 and Channel 2 showing on VTV-1 and VTV-2, respectively, each having a weight of

3.0. Bandwidth allocations for the remaining channel are also correspondingly adjusted based on the new selected single bitrate representations for them in accordance with the teachings of the present patent disclosure. A still further illustrative use case scenario **1300**A and related bandwidth allocation scheme **1300**B are shown in FIGS. **13**A and **13**B. In the scenario **1300**A, three VTV screens (VTV-1, VTV-3 and VTV-4) are within a direct view cone of the subscriber's field of view **1316**, and hence may be deemed as being looked at directly, thereby getting an equal weight of 3.0. The remaining two VD screens (VTV-2 and VTV-5) are still visible but near the visual periphery of the subscriber **1015**, which are therefore assigned a 0.75 weight. Because there is not enough bandwidth to fit all VTVs at their weights, when bandwidth is distributed, available bitrates may be chosen in an unintuitive manner in order to prevent unused bandwidth in an example embodiment of the present invention. By way of illustration, a select first VTV (e.g., VTV-1) may be arbitrarily allowed more bandwidth than the equally weighted VTVs, e.g., VTV-3 and VTV-4. Similarly, VTV-2 is at a higher bitrate than the equally weighted VTV-5, as exemplified in the bandwidth allocation scheme **1300**B of FIG. **13**B. It should be appreciated that in both cases an objective of the embodiments herein is to use all available bandwidth, even if there is not enough leftover bandwidth to upgrade all VTVs in the same weight class.

FIG. **15** depicts a block diagram of an apparatus **1500** that may be configured as an element, node or subsystem operative in an MABR communications network according to an embodiment of the present patent application. For example, apparatus **1500** may be configured in one embodiment as MVMA functionality in a gateway agent implementation such as GW **402** set forth hereinabove. In an additional or alternative embodiment, apparatus **1500** may be configured as a gateway node operative to execute or otherwise facilitate time-shifting of unwatched media content channels while providing bitrate control in a VR implementation, e.g., according to an embodiment of a combination of processes **600**A/**600**B, as will be set forth in later sections of the present patent application further below.

One or more processors **1502** may be operatively coupled to various modules that may be implemented in persistent memory for executing suitable program instructions or code portions with respect to one or more processes set forth hereinabove for facilitating channel packing, channel joining/leaving, de-gapping, and/or bandwidth allocations, etc., depending on a particular configuration. A stream IGMP management module **1512** is operative to perform various processes for generating appropriate signals to an IGMP switch and/or upstream nodes such as DSLAM nodes or BNG nodes, for joining the requested channels at selected bitrates in accordance with the teachings set forth hereinabove. An MABR bandwidth allocation module **1510** is operative to apply suitable bandwidth allocation policies to a subscriber premises pipe, including a managed video pipe serving a VR environment, under suitable program instructions, e.g., program instructions **1508** and/or other code portions in memory **1504**, or in conjunction with a bandwidth policy manager **1518** to effectuate stream bitrate selection and channel packing. A suitable segment cache **1515** may also be provided as part of or in addition to the memory system of the apparatus **1500** that is operative to store a select number of segments (for instance, a predetermined number) per each channel at select bitrates, e.g., single bitrate representations per channel. A manifest generator **1517** is configured or programmed to generate, under or as suitable program code executed by processors **1502**, a manifest referencing gateway segment cache addresses or locations (e.g., as URLs) of the stored segments in single bitrate representations, that may be provided to a VR-capable client device or CPE. In a further arrangement, apparatus **1500** may also be (re)configured to provide TSTV controller functionality **1516** for facilitating time-shifting of unwatched channels in a VR environment. Depending on the configuration, various network interfaces (I/F) **1514-1** to **1514**-K may be appropriately provided with respect to effectuating communications with, inter alia, MABR bandwidth/QoS policy manager nodes, back office nodes, SAG units and/or MSF functionalities, Session Resource Management (SRM) nodes, IGMP switches, unicast switches, BNG/DSLAM nodes, standalone or CDN edge-based TSTV systems, and the like. In similar fashion, interfaces **1514-1** to **1514**-K may also include interfaces operative to effectuate communications with a plurality of client devices, including VR-capable CPEs of a subscriber premises (in a gateway agent implementation, for example) via a suitable premises network as set forth hereinabove, for receiving stream weight updates and/or TSTV control message inputs. An HTTP server module **1506** is configured to deliver segments of the media content channels from cache **1515** at respective single bitrates to the VD screens of a subscriber's VR environment responsive to suitable http messaging processes.

Turning now to FIGS. **16**A and **16**B, depicted therein is an arrangement with respect to a subscriber premises gateway or node **1602** that may configured as apparatus **1500** set forth above according to an embodiment of the present invention for delivering select single bitrate representations of the media content channels to VD screens in addition to facilitating time-shifting of selected media content channels of a subscriber's VR environment in an example gateway implementation architecture **1600**A/**1600**B. One skilled in the art will recognize that the overall structural arrangement of the architecture **1600**A/B is substantially similar to the gateway implementation architecture **400**A/B of FIGS. **4**A-**4**B. Accordingly, the detailed description provided hereinabove with respect to FIGS. **4**A-**4**B is also applicable to the embodiment shown in FIGS. **16**A-**16**B, mutatis mutandis. An example TSTV controller **1604** of GW **1602**, responsive to receiving appropriate TS-based messages or indications from subscriber VR device **408** via an interface **1603**, is operative in association with virtual pipe stream manager **428** for interfacing with a TSTV system via suitable signaling **1606** for effectuating time-shifting of select media content channel(s) of the subscriber's VR environment **406**. As will be described below, replay or playback of time-shifted channels (TS channels) may be effectuated as unicast streams from a standalone TSTV system or a TSTV system associated with a CDN edge node for downloading by a network HTTP server, which unicast streams may be received via a unicast pipe portion **1610**A of a managed video delivery pipe **1608** serving the gateway node. Managed MABR media content channels (non-time-shifted or NTS media channels) for delivery to the subscriber's VR environment **406** may continue to take place via a managed MABR portion **1610**B of the video pipe **1608**, wherein the bandwidth may be managed by selecting appropriate bitrates as previously described.

By way of illustration, VTV **409-2** is exemplified as a VDS showing Channel 1 designated for time-shifting. A unicast stream of having a select clamped bitrate for Channel 1 is received via the unicast pipe **1610**A, which segments are passed through GW **1602**, e.g., without being cached thereat in segment cache **424**, in a unicast download path

1609 to the VR device. In contrast, it will be recalled that the segment cache **424** is used for storing media segments for the "live play" or NTS sessions provided to the NTS screens of the subscriber's VR environment **406**. As before, HTTP server **432** is operative to download the stored media segments requested by the VTVs responsive to the ABR manifest referencing the cached locations.

FIGS. **17**A and **17**B are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements, with respect to the embodiments of FIGS. **6**A and/or **6**B, in a further embodiment of the present invention for managing bitrate control in a VR environment while providing for time-shifting of media content channels. In example process **1700**A of FIG. **17**A, a change or a movement in a point of view of the subscriber in relation to a first reference axis may be detected with respect to the VD screens' placement within the VR environment (e.g., VRE **406**), as set forth at block **1702**. As noted previously, such a change or movement may result in a different viewpoint (e.g., defining or having a second reference axis) within the VR environment, wherein each VD screen is configured to receive a media content channel. Further, similar to the embodiments set forth in FIGS. **6**A/**6**B and **7**, angular distance of each of the VD screens relative to the second reference axis may be computed (block **1704**). Based on the angular distances, a determination may be made whether one or more VD screens are outside a current field of view of the subscriber (block **1706**). If so, media channels on the non-visible VD screens may be set or selected for time-shifting. Further, weights of teach of the VD screens and their media content channels may be set, reset, or otherwise updated based on the angular distance of the corresponding VD screens that are within the subscriber's field of view relative to the second reference axis, which may include assigning a null weight to each of the media content channels showing on the VD screens that are outside the subscriber's field of view, as set forth at blocks **1708** and **1710**. Subscriber's VR device may be configured to indicate the TS selections on non-visible VD screens to the serving gateway, in addition to sending the updated weights including the null or zero weights (block **1712**). Responsive to the TS selection indications, a TSTV controller of the gateway node effectuates time-shifting of the selected media content channels by providing session IDs corresponding thereto (block **1714**) to a standalone TSTV system or a CDN edge-based TSTV system depending on the implementation. The received weight/updates, including null weights, may be utilized in a channel annealing mechanism as before for selecting optimal single bitrates for each of non-TS media channels, whereby the managed MABR media pipe's bandwidth may be (re)allocated (block **1716**).

Example process flow **1700**B of FIG. **17**B is illustrative of a situation where previously time-shifted media channels of non-visible VDSs may be resumed for playback upon determining that one or more such VDSs have become visible due to a change in the user's viewpoint. As before, a determination or detection is made that the subscriber has changed her point of view to a new field of view within the subscriber's VR environment (block **1752**). Responsive to the detecting that the subscriber has changed her point of view to a new field of view within the subscriber's VR environment, a further determination may be made whether one or more VD screens that were outside the subscriber's field of view previously are now within the new field of view (block **1754**). Responsive to the determining, weights of the media content channels on the VD screens within the new field of view (including the newly visible VDSs and/or those previously VDSs that may have become non-visible in the new field of view) may be (re)assigned or updated (block **1756**). All such updates may be provided (including the null weights assigned to the new TS media content channels) to the serving gateway node for (re)allocating the bandwidth of the managed bandwidth pipe serving the subscriber's premises based on another iteration of the channel annealing mechanism (blocks **1758**, **1760**). As previously noted, only those weights that have been changed due to the change in the subscriber's FOV may be transmitted to the gateway node, i.e., a "delta" compression of weights, which transmission may be effectuated as pushing, pulling or as a request/response mechanism. Suitable session IDs and control messages to start playback of the previously time-shifted media content channels may be provided to the TSTV system, along with applicable bitrate requests based on the channel annealing operations, for facilitating delivery of the resumed media channels using a unicast at clamped bitrates (block **1762**). It will be further realized that similar to the acts of block **710**, appropriate manifest(s) may be provided to the UE/VR device by the gateway node with respect to blocks **1716** and/or **1760** responsive to bitrate selection based on channel bandwidth annealing and allocation. Moreover, the terms "allocate" and "reallocate" as well as terms of similar import may be used interchangeably in the context of the present disclosure. Likewise, terms such as "update", "assign", "reassign, and terms of similar import may also be used roughly synonymously for purposes of an embodiment of the present patent application.

Accordingly, skilled artisans will appreciate that although resumed TS channels may be accorded weights, such weights are handled differently in an example embodiment of the present invention. Consider a TSTV channel that will get a weight of 3.0 (on a visible VDS) or 0 (on a non-visible VDS) in an example. The channel annealing mechanism calculates the bitrates just like it does for MABR media channels for live sessions. Whereas for MABR media channels, the bandwidth is controlled by multicast Leave/Join operations, the bitrate for the TSTV channels is controlled by the GW node requesting the TSTV system to deliver the bitrate segments as per calculated bitrates from the annealing mechanism. If the weight is 0 then no bandwidth will be allocated to the TSTV stream and the pipe will be fully utilized for all current MABR streams. It will be appreciated that there is no need for bandwidth to be allocated for the unicast streams for channels that may be currently paused.

Embodiments of the present invention therefore provide a gateway implementation wherein gapped streams are delivered to the premises gateway for regular multicast content while unicast http content is used for TS channels since it individualized (i.e., specific to each VDS of the VR environment). The client VR device is advantageously configured to report what weights each VDS should get based on the subscriber's gaze or viewpoint, and is responsible for starting/stopping TS content as well as switching between URLs for time-shifted content or live content.

FIGS. **18**A-**18**B depict further details of a network portion **1800**A/**1800**B that may implemented as part of an example MABR network architecture of FIG. **1** for facilitating TSTV channels in a VR environment according to an embodiment for purposes of the present patent application. Similar to the network portion **300**A-C of FIGS. **3**A-**3**C, encoders **304-1** to **304**-N are operative to receive video source feeds **302-1** to **302**-N in respect of N service channels, which are provided to segmentation/gapper **306** as streams at different encoding bitrates. Each gapped service provided by segmentation/gapper **306** therefore comprises a plurality of bitrate repre-

sentations as indicated by a shorthand notation or legend **1808**, which are received IGMP switch **312**. Joined gapped services across the select bitrates may be provided to BNG **314** as before for live sessions. On the other hand, a TSTV system **1802** receives a joined gapped service that has been selected for time-shifting, as indicated by service channel path **1810**. Example TSTV system **1802** may include a database or file storage **1806** for caching the segments of the TS channels for a subscriber, which may be stored on a VDS-by-VDS basis, per subscriber IDs, as well as based on session IDs. Further, example TSTV system **1802** may be configured to provide or otherwise transmit segments of a resumed TS channel at a select bitrate to BNG **314** for delivery to the VDS via a particular subscriber pipe, e.g., pipe **318-1**, based on http mechanisms.

FIG. **19** depicts further details of a TSTV arrangement **1900** that may be used in association with the network portion embodiment shown in FIGS. **18**A/**18**B. A segment request **1908** (including TSTV session ID and select bitrate) is received by a segment selection module **1906** of example TSTV system **1802**, which generates a bandwidth limit or clamping request **1905** to a rate limiter **1904** associated with an HTTP server **1904** executing at the TSTV system **1802**. As noted previously, the select bitrate may be determined based on weight assignment with respect to the VDS in conjunction with a channel annealing process executed by the premises gateway. From a cache of segments having various bitrates, a particular representation having an appropriate bitrate **1910** (based on requested bitrate and/or bitrate clamping) may be selected for transmission to BNG **314** for eventual delivery to the requesting VDS. It should be further appreciated that BNG **314** may be constrained by network gateway policies, priorities, differential servicing and classes of service, etc., with respect to the UDP traffic.

Various illustrative use case scenarios relating to example weight assignments and associated bandwidth allocations for media content channels in a VR environment or VR space having five VD screens are set forth at FIGS. **20**A/**20**B to **23**A/**23**B, where a user/subscriber changes or shifts her viewpoints in relation to the VR spatial environment and selects different media channels to be time-shifted. Similar to the example scenario **1000**A shown in FIG. **10**A, scenario **2000**A of FIG. **20**A represents a situation where subscriber **1015** is disposed in a VR space **1002** having five VTVs VTV-1 to VTV-5 (referred to by reference numerals **1004-1** to **1004-5**) at or along different "walls" of the space **1002**. Whereas the subscriber **1015** is not viewing any VTVs directly, VTV-2 and VTV-3 are selected for or set to time-shifting. Accordingly, each of the non-TS VTVs is given a minimum available weight, e.g., 0.353, while VTV-2 and VTV-3 each get a null or zero weight. As in the example implementation of FIG. **10**A, a 360-degree field of view **1006** of the user **1015** may be partitioned into "high" weighted areas **1008**A/**1008**B, "medium" weighted areas **1010**A/**1010**B, "low" weighted areas **1012**A/**1012**B that are within the 180-degree peripheral field, the areas being demarcated in relation to the user's viewpoint line **1005** (directly looking ahead, for example, in the VR space **1002**). Non-visible areas **1014**A/**1014**B (e.g., behind-the-head areas) may be given lowest available weights possible, consistent with the example implementation of the scenario **1000**A set forth in FIG. **10**A.

Corresponding to the weight distributions provided to the VTVs in the scenario of FIG. **20**A, an example bandwidth allocation scheme **2000**B illustrates a subscriber bandwidth pipe **1052** provided to a gateway **1050** of subscriber premises that includes a VR device or apparatus **1056**. As before, the total bandwidth of the subscriber pipe **1052** may be apportioned into a 10-Mbs managed MABR video pipe **1054**A serving VR environment **1002**, a data communications pipe **1054**B as well as a voice communications pipe **1054**C. Because of the null weights assigned to VTV-2 and VTV-3, no bandwidth is allocated to the TS channels corresponding to these VTVs. Although equal weights are accorded to the remaining VTVs, VTV-1 and VTV-4 are allocated 4 Mbs each while VTV-5 is allocated only 1.6 Mbs, based on the available sample MABR bitrates, while maximizing the pipe's utilization. Accordingly, it should be appreciated that compared to the bandwidth allocation scheme **1000**B of FIG. **10**B, VTV-1 and VTV-4 now have a higher bandwidth, hence better quality of video, in the example allocation scheme **2000**B.

FIGS. **21**A and **21**B relate to another illustrative use case scenario **2100**A where a single VTV is directly viewed, another one in the peripheral vision and the remaining VTVs being unviewed, while one of unviewed VTVs is in TS mode rather than playing at a low bitrate. Similar to the scenario **1100**A shown in FIG. **11**A, a new viewpoint **1105** of the user **1015** defines a new/current reference axis in this use case scenario, with VTV-2 **1004-2** being directly viewed (which was previously in TS mode), VTV-1 **1004-1** being in a peripheral field, with VTV-3 remaining in TS mode. The weight assignment process of the present invention may therefore (re)assign or update the previously-assigned weights accordingly as shown in FIG. **21**A, which results in an allocation scheme for four non-TS VTVs as set forth in FIG. **21**B. Higher bandwidth allocation is provided for the resumed channel shown on VTV-2 because of its weight being updated to 3.0, e.g., 6 Mbs allocation as exemplified in the allocation scheme **2100**B of FIG. **21**B. VTV-1 being a peripheral screen gets an updated weight of 0.75, resulting in a smaller bandwidth allocation therefor, as before. However, VTV-4 and VTV-5 enjoy a higher bandwidth allocation than was available under the allocation scheme of **1100**B.

FIGS. **22**A and **22**B relate to example weight assignments and associated bandwidth allocation for media content channels in a VR environment having five VD screens in yet another illustrative use case scenario **2200**A where two VTVs (VTV-1 and VTV-2) are in direct view (despite VTV-2 still potentially playing non-current content, i.e., TS content), VTV-3 is in peripheral view, and remaining VTV-4 and VTV-5 are not visible at all. Corresponding bandwidth allocation scenario **2200**B accordingly illustrates 4 Mbs allocations for Channel 1 and Channel 2 showing on VTV-1 and VTV-2 (which may be showing TS content), respectively, each having a weight of 3.0. Bandwidth allocations for the remaining channel are also correspondingly adjusted based on the new selected single bitrate representations for them in accordance with the teachings of the present patent disclosure. A still further illustrative use case scenario **2300**A and related bandwidth allocation scheme **2300**B are shown in FIGS. **23**A and **23**B. In the scenario **2300**A, three VTV screens (VTV-1, VTV-3 and VTV-4) are within a direct view cone of the subscriber's field of view **1316** (similar to the scenario **1300**A of FIG. **13**A), and hence may be deemed as being looked at directly, thereby getting an equal weight of 3.0, although VTV-3 may be resuming playback of content that was previously time-shifted. The remaining two VD screens (VTV-2 and VTV-5) are still visible but near the visual periphery of the subscriber **1015**. As VTV-2 is selected for TS, it gets a weight of 0, while VTV-5 is non-TS and therefore is assigned a low 0.75 weight. Because there is not enough bandwidth to fit all four non-TS VTVs at their weights, when bandwidth is distributed, available bitrates

may be chosen in an unintuitive manner as in the bandwidth allocation scheme **1300**B of FIG. **13**B. However, it can be seen that the bandwidth allocation for VTV-3 has improved in the scheme **2300**B (4 Mbs here vs. 1.6 Mbs in scenario **1300**B) due to the reclaimed bandwidth now available because of time-shifting of VTV-2. Thus, one skilled in the art will recognize that first two screens, VTV-1 and VTV-3, in the same weight class, are arbitrarily allowed more bandwidth than VTV-4, which is also in the same weight class.

FIGS. **24**A and **24**B depict portions of a flowchart of various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate a process flow **2400**A/**2400**B for delivering TS content (i.e., playback or resumption of play) to a VD screen according to an embodiment of the present invention. At block **2402**, subscriber's VR device headset detects the subscriber's head movement. Responsive thereto, existing weights for all VD screens or TVs may be cleared (block **2404**), similar to the embodiment of FIG. **8**. Separately, the subscriber may also select TS settings for a select number of VDSs, responsive to which session setup messages may be sent to a TSTV controller of the serving gateway (blocks **2408** and **2410**). TSTV controller accordingly allocates/returns TSTV session IDs for the selected TS channels, which may be saved by the VR device for the corresponding VDSs (blocks **2412** and **2413**). This information may also be provided or used in clearing the existing weights as part of weight initialization in one implementation. At block **2406**, the VR device calculates angles for each VD screen in relation to the subscriber's field of vision. A weight-based TS delivery loop **2414** is then executed for each VD screen, which may involve at least portions of some of the embodiments set forth elsewhere in the present disclosure depending on whether or not TS is enabled for a VDS (e.g., as set forth blocks **2418** and **2420**). At blocks **2416**, a degree field or a line of field from the center of a VD screen to the center of the VR display device (or some other reference point with respect to the VR display device) is calculated, e.g., as a 0-degree reference axis. If the VDS is enabled for TS (block **2418**), the VDS's angular distance is compared against a cone of high visibility (e.g., within ±33 degrees), as set forth at block **2422**. If the TS-enabled VD screen is within this cone, the media content channel associated with that VD screen is set to having a high weight value of 3.0. The updated weight is provided to the gateway's bandwidth controller, as set forth at block **2426**. Otherwise, if the VDS is not in a predetermined cone of visibility, the associated media content channel's weight is set to null (block **2434**), which is also sent to the gateway's bandwidth controller, as set forth at block **2436**. If the TS-enabled VDS in the visibility zone is currently playing (block **2428**), the process flow exits or returns to next VDS. If the TS-enabled VDS in the visibility zone is currently not playing (block **2428**), the process flow **2400**A/B proceeds with issuing a Play message for the corresponding session ID to the gateway's TSTV controller (as set forth at block **2430**).

On the other hand, if a null-weighted VDS is currently playing (block **2438**), a Pause message for the corresponding session ID may be provided to the gateway's TSTV controller (as set forth at block **2440**). However, if the null-weighted VDS is currently not playing (block **2438**), the process flow **2400**A/B exits or returns to next VDS.

FIGS. **25**A-**25**D are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate various TSTV-related control processes that may be effectuated with respect to a TS session controlled at a gateway node, a network node, or at a cloud-centric node according to one or more embodiments of the present invention. FIG. **25**A sets forth a process **2500**A concerning starting a TSTV session. At block **2502**, a client VR device sends a request (e.g., may be generated responsive to head movement or otherwise) to start a VR TSTV session for a designated media content channel. At block **2504**, a TSTV controller sends a request to start or initiate a TSTV session for the designated channel and subscriber ID to a serving TSTV system, which responds with a session ID and associated URL for the requested channel (block **2506**). TSTV controller saves the session ID and TSTV content's URL for the requesting VDS and associated channel (block **2508**), which information is also transmitted to the VR device (block **2510**). Optionally or otherwise, if the user continues to gaze at the now TS-enabled VDS, a Play request may be generated by the TSTV controller to the TSTV system, as set at block **2512**.

FIG. **25**B depicts a process **2500**B concerning playing a TSTV session. At block **2522**, a client VR device sends a Play request (e.g., may be generated responsive to head movement or otherwise) to play a VR TSTV session for a designated media content channel with a desired bitrate. In response, at block **2524**, a TSTV controller sends a request to the MABR bandwidth control agent for playing a TSTV session for a channel having session ID and associated URL, which is then propagated to the serving TSTV system (block **2526**). At block **2528**, the TSTV system responsive to the session ID and URL information begins delivery of segments from a known point in time of the stream (e.g., at the last Pause request) or at the start of a new session.

FIG. **25**C depicts a process **2500**C concerning pausing a TSTV session. At block **2532**, a client VR device sends a Pause request (e.g., may be generated responsive to head movement or otherwise) to pause a VR TSTV session for a designated media content channel. In response, at block **2534**, a TSTV controller sends a request to the MABR bandwidth control agent for pausing a TSTV session for a channel having session ID and associated URL, which is also propagated to the serving TSTV system (block **2536**). At block **2538**, the TSTV system responsive to the session ID and URL information stops delivery of segments, the exact location of the segment at which pausing took place being stored for future use.

FIG. **25**D depicts a process **2500**D with respect to ending a TSTV session. At block **2542**, a client VR device sends a Stop request (e.g., may be generated responsive to head movement or otherwise) to end a VR TSTV session for a designated media content channel. In response, at block **2544**, a TSTV controller sends a request to the MABR bandwidth control agent for terminating a TSTV session for a channel having session ID and associated URL, which is also propagated to the serving TSTV system (block **2546**). At block **2548**, the TSTV system stops delivery of segments responsive to the session ID and URL information.

FIGS. **26**A-**26**D depict portions of a flowchart of various blocks, steps and/or acts that may be (re)combined in one or more arrangements that illustrate an example channel annealing mechanism for selecting media content channel bitrates in view of time-shifting of select channels according to one embodiment of the present patent disclosure. Skilled artisans will recognize upon reference hereto that example process flow **2600**A-**2600**D of FIGS. **26**A-**26**D is substantially similar to the embodiment **900**A-**900**D of FIGS. **9**A-**9**D. Accordingly, the detailed description provided hereinabove with respect to FIGS. **9**A-**9**D is also applied herein, mutatis mutandis.

At block **2602**, a MABR bandwidth control agent or module (e.g., associated with a VMA) receives a Join or Leave request with respect to the media content channels being provided to the VR environment. If the request is a Leave request (as per determination at block **2604**), the channel is removed from the target channel list used for annealing or channel packing (block **2608**). Also, if a TSTV controller sends a request to stop a TSTV session for a particular media channel having a designated session ID (block **2606**), that channel is also removed from the target channel list. If the request is a Join request (block **2604**), a further determination is made as to whether the stream segments are currently being delivered to the VR device or VD screens (block **2610**). If not, a "listener" process or module may be started for monitoring dynamic bandwidth channel changes (block **2612**). Otherwise, the channel is added to an active channel list (block **2614**), which feeds into an MABR virtual pipe allocation mechanism for modeling or re-modeling bandwidth allocations for the active channels (block **2620**). As set forth at block **2616**, policy management changes, if any, with respect to MABR virtual pipe allocation may also be input (e.g., from an MABR back office) into the modeling process. Furthermore, inputs from a TSTV controller (e.g., relating to playing/pausing a session) may also be provided to the pipe modeling mechanism, as set forth at block **2618**.

The active channel list may be sorted, e.g., in a descending order based on a priority value, as set forth at block **2622**, whereupon a packing iteration loop **2624** may be executed for each active channel. First, a determination may be made whether the channel's lowest bitrate representation may be accommodated into the modeled or simulated bandwidth pipe (block **2626**). If so, the channel is added to a list of applied channels along with a priority for that channel (block **2628**). Otherwise, a further determination is made at block **2630** as to whether there is a policy change to decreasing the pipe size. If so, the channel is added to a skipped channel list (block **2634**). If the channel is not the same as the new/requested channel (block **2632**), it is either added to the list of the applied channels (block **2628**) or to the skipped channel list (block **2634**).

In the exemplary embodiment of annealing flow **2600**A-D shown in FIGS. **26**A-**26**D, a message or warning **2640** may be provided with respect to each channel in the skipped channels list as set forth at a message loop process **2638**, in a manner similar to the process flow **900**A-D of FIGS. **9**A-**9**D, e.g., "Channel not currently available." For each channel in the applied channels list, a weight application process **2642** is executed wherein the weight/update received for the channel, e.g., via the listener agent monitoring (block **2636**) provided for the joined channels, as set forth at block **2644**. The applied channels list is then sorted based on the weights, e.g., in descending order, as set forth at block **2646**, whereupon a bitrate upgrade loop process **2648** is executed for each of the applied channels for arriving at an optimal bitrate for each channel, e.g., a single bitrate that can best fit the pipe. A determination is made whether the channel can be upgraded to the next highest bitrate of the available multicast bitrates using the existing MABR channel bandwidth allocation (block **2650**). If so, the bitrate for that channel is changed to that next highest bitrate (block **2651**). Otherwise, no upgrading is performed for that channel and process loop returns to the next channel in the weight-sorted applied channel list or otherwise exits (block **2653**).

Upon exiting the bitrate upgrade loop process **2648**, an IGMP loop process **2655** is performed, which involves accounting for whether an applied channel is a TS session (block **2652**). If the channel is not a TS session, a further determination is made whether the channel at the selected single bitrate representation is already connected to the correct IGMP node/port (block **2654**). If so, that channel is skipped and the loop process iterates to the next channel's single bitrate (block **2656**). If the channel at the selected bitrate is not already joined to the correct IGMP, an IGMP Join operation is performed to connect to the multicast stream having the calculated/selected multicast bitrate (block **2658**).

On the other hand, if the applied channel is a TS session, another determination may be made whether the assigned weight is 0 (block **2660**). If so, the channel bitrate is set to 0 (so as to free up the bandwidth). If the weight is non-zero, the channel bitrate is set to the calculated bitrate from the annealing process set forth hereinabove (block **2662**). In one example implementation, a TSTV system may be informed of these bitrate computations for the TS channels having corresponding session IDs (block **2666**). As one skilled in the art will recognize upon having reference hereto, the channel packing processes and/or bitrate upgrade processes of flow **2600**A-D may therefore involve one or more bandwidth pipe modeling and annealing mechanisms set forth hereinabove.

FIGS. **27**A-**27**C are flowcharts of various blocks, steps and/or acts that may be (re)combined in one or more arrangements regarding additional TSTV-related processes that may be effectuated at an example TSTV system according to one or more embodiments of the present invention. FIG. **27**A depicts a process **2700**A concerning a request to play a virtual TSTV session. At block **2702**, example TSTV system receives a Play session request for a specific session ID, with a requested delivery bitrate. Responsive thereto, the TSTV system sets a current state for the session ID as currently streaming (block **2704**). The TSTV system then performs a bitrate request handling process, e.g., including a clamping request in some implementations, for obtaining segments of a suitable bitrate (block **2706**).

FIG. **27**B depicts a process **2700**B concerning a request to pause a virtual TSTV session. At block **2712**, example TSTV system receives a request to pause a session having a specific session ID. Responsive thereto, the TSTV system suspends delivering the segments for the designated session (block **2714**). The TSTV system also sets the delivery bitrate for the session ID to zero (block **2716**).

FIG. **27**C depicts a process **2700**C concerning a request to stop a virtual TSTV session. At block **2722**, example TSTV system receives a request to stop a session having a specific session ID. Responsive thereto, the TSTV system suspends delivering the segments for the designated session (block **2724**). Similar to the process **2700**B above, the TSTV system also sets the delivery bitrate for the session ID to zero (block **2726**). Thereafter, example TSTV system purges all segments for the designated session ID (block **2728**) and provides a response including a status indication that a session having the designated session ID is stopped (block **2730**).

FIGS. **28**A-**28**C depict flowcharts or portions of various blocks, steps and/or acts that may be (re)combined in one or more arrangements relating to an example process of starting a virtual TS session and requesting bitrates for a TS session according to an embodiment of the present invention. Process flow **2800**A relates to generating a single bitrate manifest while handling a request to start a virtual TSTV session. At block **2842**, example TSTV system receives a session setup request for a designated channel and

designated subscriber. Responsive thereto, the TSTV system subscribes to all MABR bitrates for the selected channel (block **2844**). A session ID is generated with respect to the requested TSTV session (block **2846**). A time-shifted manifest file including URLs referencing captured segments across all bitrates is then generated or otherwise obtained (block **2848**). The TSTV system then strips all bitrates except the top bitrate from the manifest and responds with session ID and single top bitrate manifest URL for the designated subscriber ID to the TSTV controller (block **2850**).

Example process flow **2800**B-**2800**C shown in FIGS. **28**B-C provides additional features relating to requesting a delivery bitrate for a virtual TSTV session. At block **2802**, example TSTV system receives a delivery bitrate request for a TSTV session with a designated session ID. At block **2804**, the TSTV system saves the delivery bitrate associated with the session ID. A determination may be made whether the requested session is currently streaming (block **2806**). If not, the process flow exits (block **2810**). If the session is currently streaming, a further determination is made as to whether the requested segment is a top bitrate segment (block **2812**). If so, segment bitrate is selected based on the requested delivery bitrate (block **2822**), and the requested segment is selected for delivery (block **2844**). If the requested segment is not a top bitrate segment, a lookup may be performed based on the segment name of the requested segment, where the segment bitrate may be set to a bitrate from the manifest (block **2814**). If a segment is found at an appropriate bitrate, it is selected for delivery (block **2816**). Thereafter, either from block **2824** or from block **2816**, an http delivery system's bitrate for the designated session ID is set at the determined bitrate (block **2818**), whereupon the selected segment for the designated session ID is transmitted (block **2820**).

It should be appreciated that while one or more of the foregoing implementations are broadly GW-centric or network-centric, alternative or additional embodiments involving client-centric processes may also be practiced according to the teachings herein for allowing time-shifting to be handled primarily by the device-based logic.

Based upon the foregoing Detailed Description, it should be appreciated that one or more embodiments of the present disclosure can be advantageously implemented in a number of VR applications where bandwidth can be conserved for VD screens that are not currently being watched, thereby allowing greater bandwidth to be allocated for screens that are. By time-shifting the content, VR viewers will not miss the content, allowing the VR environment to cater to the individual viewer's surfing habits.

In the above-description of various embodiments of the present disclosure, it is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and may not be interpreted in an idealized or overly formal sense expressly so defined herein.

At least some example embodiments are described herein with reference to block diagrams and/or flowchart illustrations of computer-implemented methods, apparatus (systems and/or devices) and/or computer program products. It is understood that a block of the block diagrams and/or flowchart illustrations, and combinations of blocks in the block diagrams and/or flowchart illustrations, can be implemented by computer program instructions that are performed by one or more computer circuits. Such computer program instructions may be provided to a processor circuit of a general purpose computer circuit, special purpose computer circuit, and/or other programmable data processing circuit to produce a machine, so that the instructions, which execute via the processor of the computer and/or other programmable data processing apparatus, transform and control transistors, values stored in memory locations, and other hardware components within such circuitry to implement the functions/acts specified in the block diagrams and/or flowchart block or blocks, and thereby create means (functionality) and/or structure for implementing the functions/acts specified in the block diagrams and/or flowchart block(s). Additionally, the computer program instructions may also be stored in a tangible computer-readable medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable medium produce an article of manufacture including instructions which implement the functions/acts specified in the block diagrams and/or flowchart block or blocks.

As alluded to previously, tangible, non-transitory computer-readable medium may include an electronic, magnetic, optical, electromagnetic, or semiconductor data storage system, apparatus, or device. More specific examples of the computer-readable medium would include the following: a portable computer diskette, a random access memory (RAM) circuit, a read-only memory (ROM) circuit, an erasable programmable read-only memory (EPROM or Flash memory) circuit, a portable compact disc read-only memory (CD-ROM), and a portable digital video disc read-only memory (DVD/Blu-ray). The computer program instructions may also be loaded onto or otherwise downloaded to a computer and/or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer and/or other programmable apparatus to produce a computer-implemented process. Accordingly, embodiments of the present invention may be embodied in hardware and/or in software (including firmware, resident software, micro-code, etc.) that runs on a processor or controller, which may collectively be referred to as "circuitry," "a module" or variants thereof. Further, an example processing unit may include, by way of illustration, a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), and/or a state machine. As can be appreciated, an example processor unit may employ distributed processing in certain embodiments.

Further, in at least some additional or alternative implementations, the functions/acts described in the blocks may occur out of the order shown in the flowcharts. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved. Moreover, the functionality of a given block of the flowcharts and/or block diagrams may be separated into multiple blocks and/or the functionality of two or more blocks of the flowcharts and/or block diagrams

may be at least partially integrated. Finally, other blocks may be added/inserted between the blocks that are illustrated. Moreover, although some of the diagrams include arrows on communication paths to show a primary direction of communication, it is to be understood that communication may occur in the opposite direction relative to the depicted arrows.

One skilled in the art will further recognize that various apparatuses, subsystems, functionalities/applications and/or one or more network elements as well as the underlying network infrastructures set forth above for facilitating video outage coverage may be architected in a virtualized environment according to a network function virtualization (NFV) architecture in additional or alternative embodiments of the present patent disclosure. For instance, various physical resources, services, applications and functions set forth herein above with respect to an example ABR streaming network environment may be provided as virtual appliances, machines or functions, wherein the resources and applications are virtualized into suitable virtual network functions (VNFs) or virtual network elements (VNEs) via a suitable virtualization layer. In such embodiments, resources comprising compute resources, memory resources, and network infrastructure resources are virtualized into corresponding virtual resources wherein virtual compute resources, virtual memory resources and virtual network resources are collectively operative to support a VNF layer, whose overall management and orchestration functionality may be supported by a virtualized infrastructure manager (VIM) in conjunction with a VNF manager and an NFV orchestrator. An Operation Support System (OSS) and/or Business Support System (BSS) component may typically be provided for handling network-level functionalities such as network management, fault management, configuration management, service management, and subscriber management, etc., which may interface with VNF layer and NFV orchestration components via suitable interfaces.

Accordingly, at least a portion of an example network architecture disclosed herein may be virtualized as set forth above and architected in a cloud-computing environment comprising a shared pool of configurable virtual resources. Various pieces of software, e.g., TSTV operations, VMA and MSF functionalities, TS media/ad storage, subscriber management, etc., as well as platforms and infrastructure of a MABR network may be implemented in a service-oriented architecture, e.g., Software as a Service (SaaS), Platform as a Service (PaaS), infrastructure as a Service (IaaS) etc., with involved parties providing different features of an example embodiment of the present invention. Skilled artisans will also appreciate that such a cloud-computing environment may comprise one or more of private clouds, public clouds, hybrid clouds, community clouds, distributed clouds, multiclouds and interclouds (e.g., "cloud of clouds"), and the like.

Although various embodiments have been shown and described in detail, the claims are not limited to any particular embodiment or example. None of the above Detailed Description should be read as implying that any particular component, element, step, act, or function is essential such that it must be included in the scope of the claims. Reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural and functional equivalents to the elements of the above-described embodiments that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Accordingly, those skilled in the art will recognize that the exemplary embodiments described herein can be practiced with various modifications and alterations within the spirit and scope of the claims appended below.

The invention claimed is:

1. A bitrate control method for facilitating delivery of a plurality of media content channels to a corresponding plurality of virtual display (VD) screens presented in a virtual reality (VR) environment effectuated by a VR device of a subscriber, the plurality of media content channels being provided as respective adaptive bitrate (ABR) streams, the method comprising:

detecting, responsive to the subscriber's head movement or ocular movement, a movement in a point of view of the subscriber in relation to a first reference axis with respect to the VD screens' placement within the VR environment, the VR environment containing the plurality of VD screens, said movement resulting in a second reference axis within the VR environment, each VD screen being configured to display a respective media content channel delivered via a common managed bandwidth pipe apportioned from a total bandwidth pipe serving the subscriber's premises and each VD screen is configured to receive the respective media content channel as a respective ABR stream;

computing respective angular distances corresponding to the plurality of VD screens relative to the second reference axis irrespective of whether the subscriber is gazing at any particular corresponding VD screen;

determining that one or more VD screens are outside a field of view of the subscriber, wherein the one or more VD screens determined to be outside the field of view of the subscriber are selected for time-shifting;

updating weights assigned to each of the plurality of media content channels based on the angular distances of the corresponding VD screens relative to the second reference axis;

assigning a null weight to each of the media content channels showing on the VD screens that are outside of the subscriber's field of view;

providing the updated weights of the plurality of media content channels and indicating the time-shifting selection to a node operating to serve the subscriber premises; and

receiving from the node a manifest indicating respective single bitrate representations of each of the plurality of media content channels, wherein each media content channel is stored in a segment cache associated with the node as a plurality of segments encoded in multiple bitrate representations, the respective single bitrate representations of the media content channels being selected by the node based on the updated weights provided by the subscriber's VR device.

2. The method as recited in claim **1**, wherein the angular distance computed for each of the plurality of VD screens comprises at least one of an angular deviation along a horizontal plane, along a vertical plane, or both planes, the horizontal and vertical planes defined in the VR environment relative to the second reference axis.

3. The method as recited in claim **1**, wherein the angular distance is computed in at least one of radians, degrees, or both.

4. The method as recited in claim **1**, wherein at least a portion of the plurality of VD screens are presented along a real world object in an augmented reality (AR) application.

5. The method as recited in claim **1**, wherein only the weights that are updated to values different from values

previously assigned to the plurality of media content channels are provided to the node serving the subscriber premises.

6. A virtual reality (VR) apparatus, comprising:

a hardware platform including one or more processors for executing a media content application;

a head-mounted display (HMD) device operative with the hardware platform to effectuate a VR environment that includes a plurality of virtual display (VD) screens; and

one or more persistent memory modules having program instructions stored thereon which, when executed by the one or more processors, perform the following in association with the media content application:

detect, responsive to the subscriber's head movement or ocular movement, a movement in a point of view of a subscriber using the VR apparatus, the movement in relation to a first reference axis with respect to the VD screens' placement within the VR environment, said movement resulting in a second reference axis within the VR environment, the VR environment containing the plurality of VD screens, the plurality of VD screens being configured to display respective media content channels delivered via a common managed bandwidth pipe apportioned from a total bandwidth pipe serving the subscriber's premises and each VD screen is configured to receive a respective media content channel as an adaptive bitrate (ABR) segment stream,

compute respective angular distances corresponding to the plurality of VD screens relative to the second reference axis irrespective of whether the subscriber is gazing at any particular corresponding VD screen,

determine that one or more VD screens are outside a field of view of the subscriber, wherein the one or more VD screens determined to be outside the field of view of the subscriber are selected for time-shifting,

update weights assigned to each of the plurality of media content channels based on the angular distances of the corresponding VD screens relative to the second reference axis,

assign a null weight to each of the media content channels showing on the VD screens that are outside of the subscriber's field of view,

provide the updated weights of the plurality of media content channels and an indication of the time-shifting selection to a node operating to serve the subscriber premises, and

receive from the node a manifest indicating respective single bitrate representations of each of the plurality of media content channels, wherein each media content channel is stored in a segment cache associated with the node as a plurality of segments encoded in multiple bitrate representations, the respective single bitrate representations of the media content channels selected by the node based on the updated weights provided by the subscriber's VR apparatus.

7. The VR apparatus as recited in claim **6**, wherein the angular distance is computed for each of the plurality of VD screens along a horizontal plane in at least one of radians, degrees, or both.

8. The VR apparatus as recited in claim **6**, wherein the angular distance is computed for each of the plurality of VD screens along a vertical plane in at least one of radians, degrees, or both.

9. The VR apparatus as recited in claim **6**, wherein the plurality of VD screens comprise one or more virtualized TV screens, virtualized gaming monitors, virtualized tablets, virtualized phablets, virtualized computer monitors, and virtualized projector screens.

10. The VR apparatus as recited in claim **6**, wherein the HMD device is operative to effectuate an immersive VR environment in which the subscriber can perform a movement in full 360° in one of a vertical plane, a horizontal plane, or both planes, defined in the VR environment.

11. The VR apparatus as recited in claim **6**, wherein the HMD device is operative to effectuate an immersive VR environment in which the subscriber can perform a movement limited to less than 360° in one of a vertical plane, a horizontal plane, or both planes, defined in the VR environment.

12. The VR apparatus as recited in claim **6**, wherein the hardware platform comprises a personal computer, a laptop computer, a smartphone, a tablet, a phablet, and/or a gaming console.

13. The VR apparatus as recited in claim **6**, wherein the HMD device is operative to superimpose or overlay the VR environment over a real world object in an augmented reality (AR) application.

14. The VR apparatus as recited in claim **6**, wherein the program instructions for providing the updated weights to the node serving the subscriber premises comprise instructions for providing only the weights that are updated to values different from values previously assigned to the plurality of media content channels.

15. A non-transitory computer-readable medium having program instructions stored thereon which, when executed by a processor of a virtual reality (VR) device of a subscriber, facilitate delivery of media content to a plurality of virtual display (VD) screens presented in a virtual reality (VR) environment effectuated by the VR device of the subscriber, the program instructions configured to perform following steps:

detecting, responsive to the subscriber's head movement or ocular movement, a movement in a point of view of the subscriber in relation to a first reference axis with respect to the VD screens' placement within the VR environment, the VR environment containing the plurality of VD screens, said movement resulting in a second reference axis within the VR environment, the plurality of VD screens being configured to display respective media content channels delivered via a common managed bandwidth pipe apportioned from a total bandwidth pipe serving the subscriber's premises and each VD screen is configured to receive a respective media content channel as an adaptive bitrate (ABR) stream;

computing respective angular distances corresponding to the plurality of VD screens relative to the second reference axis irrespective of whether the subscriber is gazing at any particular corresponding VD screen;

determining that one or more VD screens are outside a field of view of the subscriber, wherein the one or more VD screens determined to be outside the field of view of the subscriber are selected for time-shifting;

updating weights assigned to each of the plurality of media content channels based on the angular distances of the corresponding VD screens relative to the second reference axis;

assigning a null weight to each of the media content channels showing on the VD screens that are outside of the subscriber's field of view;

providing the updated weights of the plurality of media content channels and indicating the time-shifting selection to a node operating to serve the subscriber premises; and

receiving from the node a manifest indicating respective single bitrate representations of each of the plurality of media content channels, wherein each media content channel is stored in a segment cache associated with the node as a plurality of segments encoded in multiple bitrate representations, the respective single bitrate representations of the media content channels selected by the node based on the updated weights provided by the subscriber's VR device.

16. The non-transitory computer-readable medium as recited in claim **15**, wherein the angular distance computed for each of the plurality of VD screens comprises at least one of an angular deviation along a horizontal plane, along a vertical plane, or both planes, the horizontal and vertical planes defined in the VR environment relative to the second reference axis.

17. The non-transitory computer-readable medium as recited in claim **15**, wherein the angular distance is computed in at least one of radians, degrees, or both.

18. The non-transitory computer-readable medium as recited in claim **15**, wherein at least a portion of the plurality of VD screens are presented along a real world object in an augmented reality (AR) application.

19. The non-transitory computer-readable medium as recited in claim **15**, wherein the program instructions for providing the updated weights to the node serving the subscriber premises comprise instructions for providing only the weights that are updated to values different from values previously assigned to the plurality of media content channels.

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